THE TRAINING OF THE APPLE TREE

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SUMMARY AND CONCLUSIONS.

To successfully meet the increasing competition in marketing apples, the Massachusetts Apple Grower must produce high colored and the best quality apples at the lowest possible expense. Proper training of the tree is essential to the production of such fruit. This thesis discusses all the factors of training apple trees and gives a new system of training, based on five years study of apple trees and one year of experiments in growing the trees.

Directions for training trees are largely empirical, but there is an increasing fund of exact advice accumulating through experiments.

A system of training for any locality should be based on the habit of growth of the varieties and modifying factors of soil and climate. Under the same conditions different varieties require different treatment. Apple trees are trained to the Vase or Globular, Leader and Modified Leader types of head. The Globular head is condemned as it is often structurally weak, it does not offer the best distribution of fruiting wood and is difficult and costly to train. The Leader type is recommended for New England since it conforms to the natural habit of growth of the apple tree. It offers the greatest bearing surface and the best distribution of fruiting wood and is easy and cheap to train. The Modified Leader is an improvement over the Globular type. It has not been extensively used in the East.

Studies of a number of Globular, Leader, and Modified Leader trees show that there is no difference in height of these types as found in the orchards studied.

The primary scaffold branches of a tree should form a wide angle with the trunk, so as to make a strong union between branch and trunk.

The scaffold branches should be spread in growth in order that the largest bearing surface may be obtained and the tree kept open so as to insure the development of fruit throughout the entire top.

The primary scaffold branches should be separated eight inches or more on the trunk, the distance depending on the variety. This separation

of branches permits light to enter all parts of the trees and develop fruit buds and mature and color fruit. Fungus diseases are checked and the orchard operations of spraying, pruning, thinning and picking are facilitated and cheapened.

In planting apple trees the distance for leader trees should not be less than fifty feet. Sixty feet would be better. Fillers may be used but must be removed before crowding occurs. The primary scaffold branches should not be cut back at planting. The surplus branches may be cut out or cut back to stubs and allowed to remain for one or two years before being removed. The young tree should be pruned as lightly as possible, so that fruit bearing will be encouraged. Bearing trees should not be pruned heavily since such pruning encourages wood growth at the expense of fruit bearing.

Summer pruning is not advised for New England.

Heading back the apple tree is injudicious, since such practice fills the top with twigs and shades the interior of the tree.

The pruning operations should consist largely of thinning the top to admit light to all parts of the tree and correct faulty growths. To realize the greatest profits the fruit should be thinned.

In 1915, several hundred trees were experimented on in the nursery to study the development of branches, branch angles, bud growth, effect of severe disbudding on whips, the spacing of scaffold branches, and the number of seasons required in the development of the modified leader.

In these experiments all the primary scaffold branches were spaced eight inches or more apart.

Experiment I. Whips having a terminal bud and three, four, or five buds chosen for scaffold limbs after growth had progressed about an inch. Intervening buds removed.

Experiment II. Whips having terminal bud removed, but treated with this exception in the same manner as Experiment I.

Experiment III. Whips unpruned. Two lots A in which the buds were stripped off the trunk and B with all buds left on the trunk.

Experiment IV. Two year old trees pruned with a leader and one or two scaffold limbs saved eight inches apart. The leader treated as in Experiment I.

Experiment V. To test the ability of a bud or short spur (Prong bud) to develop into a primary scaffold limb or a two year or older tree.

Results were as follows:

In Experimente I, II, III, and IV by severe disbudding and separating limbs on whips of Baldwins, Wealthy, and McIntosh it was found that as an average, three permanent limbs could be secured and in many cases four or five. Modified leader trees with three to five branches can often be thus headed in one year, and in all cases in two years.

Experiments I, II, and IV showed that the removal of most of the buds on the whip or leader produced many upright growing limbs. The lowest limb was usually the widest spreading and the upper limb the most upright.

Experiments I, II, and IV produced the narrowest branch angles. Experiment III the widest angles. Thus in Baldwin, Wealthy and McIntosh and in Experiment III the angles of the first limb averaged 80° while in Experiments I, II and IV the average was from 34° to 66°.

As revealed in the measurements of angles and spread as practiced in Experiments I, II, and IV the removal of buds or severe early disbudding is not a judicious practice to follow in heading trees.

The general results of Experiment IV aside from the effect of the disbudding process show that one or more limbs can be retained on a two year old tree, with the remaining limbs cut away. The retained limbs will not out grow the leader.

In 48 Baldwin, Wealthy, McIntosh and Wagner having from one to three limbs saved only one tree had a limb out grow the leader. In Experiment V it was found that auxiliary buds or "Prong Buds" could be

developed into scaffold limbs by severe early disbudding in the spring.

Caliper measurements of the trunk o f trees disbudded and not disbudded after planting showed that the disbudding checked growth. Non disbudded Wagner trees increased in growth of trunk 2 to 4 millimeters or more over disbudded trees.

A number of measurements were made on the unpruned leaders of Wagner, Wealthy and Duchess trees. It was found that on two year old wood there was an average ofone branch, on the three year old wood an average of three branches for Duchess and Wagner and four branches for Wealthy. These results indicate that the necessary scaffold limbs for the framework cannot be secured until the growth of the leader is over two years old.

The author wishes to express his gratitude to Dr. J. K. Shaw for making possible the experimental work incorporated in this thesis and for many helpful suggestions.

INTRODUCTION

The New England Apple Grower has recently entered a period, in which he is encountering keen competition in marketing his fruit. This competition is of two kinds, that with different fruits and the other with competing apple growing sections of the United States.

Due to successful cooperation in the Citrus Fruit Industry of California and Florida and a monopoly in the case of the Banana trade, powerful organizations are marketing these fruits. Large sums of money are also being expended in all parts of the United States by the California and Florida Orange Growers in advertising citrus fruits. This advertising campaign is rapidly increasing the consumption of these fruits. It is also stated that recently the banana consumption was more than doubled in the United States. On the other hand, the consumption of apples has not increased, in fact statistics show that it has actually decreased. This is due in part to the competition of other fruits.

Many thousands of acres of apple trees in the West and East are now bearing or are soon coming into bearing. This fact assures a greater production and thus keener competition in the near future.

The chief rivals of New England in the production of high quality apples will be the Western States of Oregon, Washington and Colorado and in the east the Appalachian Mountain states of Pennsylvania, Virginia and West Virginia. All these regions produce apples of superior appearance and bright red color.

To successfully compete with the Western and Appalachian apple growers and other competitive fruits, the New England Apple Grower must produce apples of the highest color, free from blemishes, with a low production and marketing cost.

Color is an important factor in selling apples. People always seem to associate a bright red color with high quality. In addition, the Western Growers are educating the consumer to demand a fine appearing apple. The Western apples have a smooth waxen appearance, of bright red color and free from blemishes. This fact is of great moment to New England Apple Growers, for it is possible to produce apples here, having as high color with an attractive waxen appearance and free from blemishes, as in any other part of the United States.

An important factor in growing such high quality fruit is that a proper system of training the trees be adopted and

consistantly followed. Such a system must provide for the production of maximum crops of highest quality fruit at the lowest cost commensurate with the results. These results can only be obtained when the fruit grower adopts a system of training that distributes the branches in such a manner that light is admitted to all parts of the tree to produce the fruit buds and to color the fruit. With an open distribution of branches, spraying is done more thoroughly, thus checking insects and fungus diseases, and thinning and picking fruit is facilitated, which reduces the cost of handling. The size of the crop, precocity in bearing and cost of pruning operations are all influenced by the system of training adopted.

OBJECT

The object of this thesis is to thoroughly discuss the whole problem of training apple trees, and in so doing to call attention to certain fallacious practices sometimes met with in New England training; to define terms that have led to some confusion in the past; to examine contrary advice and different methods and the reasons for the same; and, finally, to offer a method for training trees in New England that is founded on all the factors affecting the growth of the tree and thus controlling the training operations. This method is based on observations of many trees and orchards and experiments carried on at Amherst by the author, and on experiments of others conducted elsewhere.

The writer's interest in training and pruning trees was awakened when he attempted to teach the subject. He found so many contradictory ideas, different methods used and dogmatic advice given, that it was very difficult to lecture and demonstrate the training of apple trees, with the honest conviction that he was imparting the truth. From that time on a study was made of fruit trees, and apple trees in particular of all ages, in order to discover the fundamental principles underlying the correct training of trees, as applied to New England conditions.

LITERATURE ON TRAINING

The literature on the training and pruning of apple trees is voluminous. It might be divided into two classes, first that which is emperical, comprising the bulk of the writing and secondly that based on experiment, which is supposed to be scientifically accurate.

Foreign Literature

The European and English writers from the earliest to the latest, largely confine their attention to the training of trees in fancy forms on walls and in gardens. Much that they do is of interest, but of little practical value to the American Orchardist. Some of the early English authors such as Thomas Andrew Knight (1) made many valuable suggestions on training apple trees. The best English publications on training have eminated from the Woburn Experiment Station. The results of carefully conducted experiments by S. W. Pickering (2) as published in the reports of this station, should be read by every one interested in the experimental side of Pomology. These results are quoted several times in this thesis.

In Australia, New Zealand and South Africa literature on training apple trees has appeared since 1890. Most of these writings are in the reports of the various State Board of Agriculture of these countries.

The development of the science of Pomology in the United States, from the first years of the 19th century until the rise of large commercial orchards shortly after the Civil War, was largely concerned with the study of varieties. The methods of training were to a great extent, derived from the French and English, having been inspired by Knight, Forsythe and Du Breuil. The publications of this time denote little or no attention to pruning standard trees, but have a short chapter on training to fancy forms.

During the latter part of the 19th century the studies of varieties languished. With the rise of the Experiment Stations the attention of Pomologists centered on methods of culture and spraying, which was of pressing importance at this time, due to the increase of orchard pests.

Recently the interest in questions pertaining to training trees has been greatly stimulated, with the result that practically all the Experimant Stations, located in apple growing states, are doing some research on these problems.

American Literature of the Nineteenth Century on Training.

The first American publication that has been found by the writer, which containe directions on training and pruning adapted to commercial orchards is that of Thacher (3) 1822. For heading, the author advises as follows: "All superfluous or rambling branches should be taken off annually and only three or four leading shoots be left to every head." On pruning bearing trees general directions are given as to time, keeping the tree open, on methods of cutting large limbs, removing crossing branches and dead wood. With but one marked exception the advice given by this early author is little different and in many cases much more correct than that offered by his successors even to this day. Kenrick (4) 1833 makes no mention of training of standard trees. In the edition of 1841, he says of orchard trees: "If the branches of a young tree, issuing at and above the requisite height, be made by pruning, to diverge from the trunk in every direction above the horizontal, and the interior of these be carefully kept from any interference with each other for a few years, little pruning will even afterwards be necessary."

Thomas (5) 1846 has passed through many editions the last being in 1911. In the first edition of 1846 the training advice is general such as time of year etc. In the 21st edition as revised by Wood the training directions are as follows: "On planting, three or four branches are selected and cut back, the amount of cutting being left to the judgment of the operator. Two buds are allowed to grow on these branches, the remaining buds being rubbed off. This operation is repeated the following year on the new shoots and continued until the head is formed. Such a tree is essentially pruned to the rounded headed form, the leader being suppressed. The chief rules for pruning a bearing orchard are given. (1) To avoid cutting off large limbs except in case of absolute necessity. (2) To admit light equally into all parts of the tree by thinning. (3) To remove all crooked or badly growing limbs. (4) To do the work gradually or in successive years. (5) To cover wounds over an inch in diameter with shellac. No further advice is given."

Why the advice of Downing (6) 1857, the foremost Pomologist of his time should have made so little impression on the training and pruning methods of the fruit growers from 1850 to 1900 seems remarkable. The writer's impression is that Thomas and also Barry were able to over shadow Downing and command the attention of the Pomologists and orchard men. The fact remains, nevertheless, that since the time of these two men up to today the severe pruning of apple trees has been most generally advised.

Downing says: "In this country almost all fruit trees are grown as standards. In this way they develop their natured forms, attain the largest size, and produce the greatest quantity of fruit, with the least possible care. Our bright and powerful sun, reaching every part of the tree, renders the minute system of pruning and training, which occupys so large a portion of the English works on this subject, of little or no moment to the cultivator here."

"A judicious pruning to modify the form of our standard trees is nearly all that is required in ordinary practice. Every fruit tree, grown in the open orchard or garden as a common standard should be allowed to take its natural form, the whole efforts of the pruner going no further than to take out all weak and crowded branches. Where pruning is not required to renovate the vigor of an enfeebled tree, or to regulate its shape--in other words, in the case of a healthy tree which we wish to retain in a state of the greatest luxuriance, health, and vigor, it may be considered worse than useless."

Warder (7) 1867 a prominent Pomologist of the middle 19th century gave very general directions for training similiar to Thomas and Barry.

Barry (6) 1883 gives the usual phyeiological effects and mechanical methods of pruning. For standards, he says, select a nursery tree four to six feet high. Choose three or four limbs to form the head and cut back these at least one half. From the shoots produced on these, at and below the cut, two of the strongest growths are selected, each on opposite sides and the others are rubbed off. The attention required after this will be to maintain a uniform growth among these six branches and their members and divisions. Prevent the growth of shoots

in the center. The leading defect in all our orchard trees is too much wood and the heads are kept so dense with small shoots that the sun and air, are in a great measure, excluded and the fruit on the outside of the tree only is marketable or fit for use. The head should be kept open rather in the form of a vase.

The most comprehensive American work on training fruit trees is that of Bailey (9) 1898, which has been revised a number of times. Bailey's writing covers the field of training and pruning all kinds of fruits in a most exhausive manner. However the writer fails to find anything of originality, pertaining to the training of apple trees in this work. The publication is mainly a restatement and compilation of the work of American, French and English Pomologists, written in an attractive style, with observations and suggestions of the author, which help greatly in making the subject clear. Bailey states the following as the reasons for training and pruning.

(1) To modify the vigor of the plant.
(2) To produce larger and better fruit and flowers.
(3) To keep the plant within manageable shape and limits.
(4) To change the habit of the plant from more or less wood bearing to fruit bearing.
(5) To remove superfluous and injured parts.
(6) To facilitate spraying and harvesting.
(7) To facilitate tillage and to improve the convenience of the plantation.
(8) To train the plant to some desired form.

The following are given as the principles of pruning and consist largely of the physiological effects of pruning.

(1) Heavy pruning of the top of a plant tends to increase the production of wood.
(2) Heavy pruning of the root tends to lessen the production of the wood.
(3) Heavy pruning of the top tends to rejuvenate weak or declining plants.
(4) A pruned plant tends to resume its natural habit.
(5) The habit of the plant varies from youth to age.
(6) One part of a plant may live at the expense of another part.
(7) Water sprouts are results of a disturbed equilibrum.

(8) The tendency of plants is to grow from the uppermost buds.
(9) The heading in of young growths tends to develop the lateral and dormant buds.
10) Checking growth, so long as the plant remains strong and healthy, induces fruitfulness.
(11) Fruit bearing is determined more by the habitual performance and condition of the plant than by the kind or extent of pruning, it is associated with a quiescent rather than a stimulated or fitful state and the habit is more amenable to treatment when the plant is young than when it is old.
(12) Pruning may be made a means of thinning the fruit.
(13) Heading-in induces fruitfulness by checking exuberant growth and by encouraging the formation of short lateral growths.
(14) The season in which pruning is done has some influence on fruit bearing, for winter pruning tends to produce wood where as summer pruning does not.
(15) The effect of pruning as well as the necessity of it depends greatly upon locality and climate.
(16) Deals with the healing of large wounds.

Bailey perfers the "double story" (leader) type of head, with four or five scaffold limbs. The advantages claimed for this type of tree is that it offers a greater surface for bearing fruit, the load is more evenly distributed and there is less danger of splitting crotches.

In starting the heads on young trees he advises cutting back the scaffold branches to a few buds each. In succeeding years the training consists of the usual thinning and cutting crossing branches and heading back of vigorous leaders.

Experiment Station Literature.

Due to the fact that comprehensive pruning experience requires a long time for the obtaining of results, the Experiment Stations have been reluctant to undertake such research. It is only within the past five or six years that extensive experiments in training apple trees have been undertaken. Recently several bulletins recording results based on experiments in training and pruning have appeared. But prior to 1912, with a few marked exceptions, the Experiment Station Literature on this subject contains very little of originality as to methods.

About 1900 there was a great revival of interest in apple growing. The demands on the Experiment Station for advice on apple growing, and incidentally training and pruning, were very great. This resulted in the production of one or more bulletins by nearly every Experiment Station located in an apple growing state.

In order to clearly demonstrate the various methods of training and pruning apple trees, as advocated since 1900, a number of Experiment Stationsbulletins and writings from other publications are here given. Each of these writings are considered typical, either as to the methods quoted of a particular region, or for methods quoted in general, as having certain

unique features, or as an example as a departure from the prevailing mode, being based on local observations and experiments and not compiled from the writings of others.

These publications have in some cases been abstracted in part, and in others copied verbatim. Heavy type is used to emphasize certain features of these writings.

Paddock (10) advises training as follows, which is typical of the Western method, and has been extensively copied in the East.

"The Vase form of tree is favored with not more than five scaffold limbs. The danger of the leader being infected with blight and having to be cut out is claimed as a disadvantage, also leader trees are started to be high headed trees. The head is started at 20 inches and the branches retained are cut back to a sound bud a few inches from the main stem. If the tree is poorly headed, prune to whip, leaving about 18 inches of trunk to form head on or plant a whip and cut back accordingly."

"The second season the three or five scaffold limbs that have been selected are cut back to 12 inches from the trunk. If the lowest branch starts, at 20 inches from the ground and the highest branch should be one or two feet above. For the third year pruning two laterals are allowed to develop on each scaffold limb and are cut back from a half to two thirds their growth. From now on pruning consists in removing surplus branches and those that cross. Vigorous growths also are headed in."

Fisher's (11) advice is quite similiar. "There are two distinct systems practiced in the Northwest in forming the tops of apple trees. The first is known as the pyramidal form in which the leader is preserved and the branches trained out from it. The second form is that of a vase in which the leader is removed and the branches take the form of the ribs in an inverted umbrella. Not more than four limbs are used to form the framework, or the top of such tree. The result is an open centered tree which gives a larger surface on which the sun can shine. Such trees are usually nearer the ground."

"The shape of the tree, however, should be determined largely by the natural characteristics of the tree. Some varieties grow best when the leader is preserved, while others produce the best results where the leader is cut out and the open centered tree is formed. In the open centered tree it is necessary to form braces accross from the limbs to keep them from splitting when producing a heavy crop of fruit. Trees that are headed low (from 18 to 24 inches) produce the best results in Montana."

"If one year old trees are set out, the pruning the first year will consist in cutting the top back to within 18 or 24 inches of the ground.

During the first season three or four branches should be permitted to grow. In the spring of the second year if more than three or four branches grew during the first summer, they should be cut out. The remaining branches should be cut back to within three or four buds of the main stem. If the urn shaped or open centered tree is to be grown, the leader should be cut entirely out at this time. If the pyramidal tree is the one desired, the leader is not cut out entirely but is cut back to within three or four buds of the season's growth. In the spring of the third year each lateral branch is treated much the same as the main stem and lateral branches during the first and second years. All but three or four branches are cut out including the terminal branch and the others are cut back to within three or four buds of the stem from which they grew. By cutting each season's growth back to within a few buds of the last season's growth the tree is made to grow much stockier than it otherwise would."

Jarvis 12 plagiarizes the western method for Connecticut.

"For most varieties the head should be started not more than two feet above the graft union, but with some naturally spreading varieties, like Rhode Island Greening, start the head at three feet. On two year olds, if the heads have been started right, thin out the branches to three or four and cut these back to within three or four inches of the stem."

"The regular annual pruning consists in removing unnecessary growth and moderately heading-in the stronger growing branches. There is a tendency among the best growers to develop a tree with an open space in the center of the head. To spread a tree cut to an outer bud and to compact the head cut to an inner bud."

Close (13) advises the conventional method for Maryland.

"Select from 3 to 5 branches distributed around the trunk at different heights to form the foundation branches. Cut these back to from four to six inches in length. Cut the other branches above the second or third bud, rather than short up to the trunk. This promotes the development of more leaf surface, which induces increased growth. If the tree is to be low headed the top should be cut off one and one half or two feet above ground, if high headed at about four feet from the ground.

1st year. This consists of the pruning done when the trees are planted, but if any new shoots tend to make the trees unsymmetrical the tips should be pinched off in summer to check their growth.

2nd year. Cut out all surplus branches and prune back the foundation branches from one third to one-half of their growth making the tree symmetrical and leaving the central leading shoot longer than the others. Avoid the formation of crotches as they are sure to split down and ruin the trees.

3rd. Prune as mentioned for second year. Do not let two branches cross or rub; remove one.

4th. Until the trees begin to bear, the foundation branches should be cut back annually to make them short and strong. After fruiting begins not much pruning is necessary except to thin out surplus growths and keep the tree symmetrical. Prune from the top down and not from the bottom up.

"Careful summer pruning is of immense importance because the new growth can be so easily guided and controlled . Young trees ought to be examined every three or four weeks in the growing season when much of the pruning can be done by pinching out new growths with the thumb and finger where necessary. It sometimes happens that young trees grow so vigorously they do not begin to bear fruit for several years after they should be producing crop. This tendency toward wood production can often be checked and fruit production induced by rather severe pruning early in June."

Hedrick (14), the foremost Pomologist in the United States and one of the leading Pomological Scientists in the World, breaks away from the western vase type, severely pruned trees and advocates a system of training adapted to humid regions as the Eastern United States. Hedricks writings are based on long experience and exhaustive research.

Pruning Fruit Trees

"It is necessary to cut away part of the branches to enable the injured root system to supply the remaining branches with water. The less the roots are injured the less the top need be cut away. Both theory and experience lead to the belief that fruit growers usually make a mistake in the manner of pruning newly set trees. The common way is to cut back all of the branches. This, in many cases is wrong. The top buds on a branch develop soonest and produce the largest leaves. Now a newly set tree will grow best if it can develop a large leaf surface before dry, hot weather sets in, and this it will do if some branches are left intact. Therefore, instead of shortening-in all branches, cut away some of the branches entirely. The tree so pruned will start growth and acquire vigor more quickly and a better top can be formed. There are some cases in which certain fruits or varieties produce abnormally long branches by the end of the second year which may have to be cut back.

"The first pruning.--Remove the branches and cut back the remaining whip to the heading height desired. The reason for this cutting back is that a tree of this age has not sufficient space of bare trunk between branches for final branch spacing. If the tree is two years old, as is usually the case with all fruits excepting the peach, or when the one year old plants have been set a year, the real work of heading may be begun, but even now the required space for proper heading hardly exists, and the head cannot yet be wholly formed. This early pruning is, therefore, all more or less provisional though an ideal for the future tree must be plainly in the mind from the start.

"The height of the head.-- A decisive choice must be made at the very start as to the height of the head. Shall the tree below or high-headed? The choice should usually be for a low headed tree.

"The form of the top.--Two general types of top are open to choice; the vase form or open centered tree, and the globe or close-centered tree. In the first the framework of the tree consists of a short trunk surmounted by four or five main branches ascending obliquely. In the close-centered tree the trunk is continued above the branches, forming the center of the tree. There are several modifications of each of these. In this climate the open-headed, vase-formed tree is best for the peach and the close-centered two-story tree is best for all other fruits. Whatever the form, care should be taken that the lowest branches are longest, so that the greatest possible leaf-surface will be exposed to the sun and light.

"Tree formation.--For several years after planting, the peach alone excepted, fruit trees need to be pruned only to train the tree. Just how much to prune young trees depends upon the fruit, the variety, the soil and the climate. Fruit growers prune trees far too much, thereby increasing the growth of wood and of leaf surface and delaying the fruiting of the plant. If trees were originally well selected all that is needed is to remove an occasional branch which starts out in the wrong place -- the sooner done the better -- and to take out dead, injured or crossed limbs. The peach, some plums and some pears may need heading-in, and a weak or sickly tree may require somewhat more severe pruning.

"Pruning for wood. -- When the head of the tree is formed subsequent pruning is directed toward the formation of wood or of fruit-buds. If a tree is bearing many small fruits, if the top contains dead or dying branches, or if the seasonal growth is short and scant, it may be taken for granted that

the tree lacks vigor, or, in old trees, is passing into decrepitude. Such trees may usually be rejuvenated by judicious pruning. In professional terms the tree must be "pruned for wood." Such pruning consists in cutting back a considerable number of branches and in wholly removing others. The practice is based upon the fact that the development of leavee and shoots — vegetative activity — is dependent upon a constant supply of the soluble nutriment — the sap. Therefore, when the size of the tree-top is diminished the remaining parts grow more lustily. If half of the top of a decrepit tree is cut away, the remaining half in the season that follows will produce a leaf surface often twice that which the whole top would have borne. When trees are enfeebled by age, injured by insects or fungi, robbed of food and moisture by sod or crops, or neglected in any way, there is nothing which will more quickly stimulate them and renew their youthful vigor than conservative surgery. Such pruning should usually be extended over two or more years.

"Pruning for fruit. — A barren tree can sometimes be made to bear fruit by proper pruning. Not infrequently barrenness is caused by over-manuring or over-stimulation of some kind, because of which the number of shoots and leavee and the size of the same are greatly increased, but flower buds do not form. This over-production of wood and leaf can sometimes be stopped by breaking or cutting off the greater portion of the season's growth in late summer. The philosophy of such pruning is that in taking away the greater part of these growing shoots we deprive the tree of the parts which are making greatest demands upon the nutritive powers of the plant, and this permits the lower buds to enlarge and store up more reserve food, a condition necessary to the formation of fruit-buds. Summer pruning is a weakening process and in our climate may greatly decrease the vigor of the plants if frequently resorted to. The practice is neither common nor often necessary in this State except in the case of dwarf apples and pears.

"Summer pruning must be done when the elongation of shoots has ceased for the season. The time cannot be stated definitely but in this climate it is about the first of August. Emphasis must be put upon the fact that this pruning should not be done at a fixed time, all depends upon the season. In our inequable climate it is very difficult to practice summer pruning successfully, and it is probably best, instead of cutting off the ends of the young shoots, to break them off and let them hang, cutting them in the winter. Such breaking is an aid in preventing second growths. Usually in this operation at least half of the young growth should be removed. In closing the topic it must be said that summer pruning is a matter of special resort."

More (15) also advises the western system for the Mississippi Valley.

> "For upright growing varieties like Wealthy and Northwestern, 18 to 2 ft. will be sufficient.Spreading varieties with slender branches should be headed somewhat higher."

"The branches should be well distributed around the trunk and sufficient in number so that if any form V shaped crotches they may be removed. Usually four or five branches will be sufficient."

"In Wisconsin, with our short growing season, the open centered form is most desirable. Cut out the center leader."

"Four branches are sufficient and frequently three on strong growing trees will be enough. If too many branches are left at the start, the top becomes too thick, necessitating the removal of one or more later on."

"The main branches are usually cut back, leaving them from six to eighteen inches long."

"Pruning the young tree the second year consists in removing the superfluous branches which have been formed on the main branches chosen at the first pruning and in shortening the growth. The tendency to leave too many branches the second year is almost as great as the first pruning. Those chosen on the main branches (two or three) should be shortened or headed in. Occasionally heading in will not be necessary, but as a rule from one to two thirds the past seasons growth should be removed. Branches growing upright cut to outer bud, etc."

Stewart (16) retains some of the western ideas for Pennsylvania, but breaks away from the prevailing severe pruning having been influenced by the work of Pickiring at Woburn, England. Due to advocating the vase type of tree, he is compelled to advise heading back and thinning the top in order to enable the tree to carry the load and admit light to the fruit.

"If one year old, "whips" are used the only pruning needed is to cut them off at the height desired."

"In general a height of twenty-five to thirty inches is low enough for the lowest permanent limb to appear.

Above this a further space of at least twelve to fifteen inches should be allowed to permit the frame work limbs to appear at sufficient distances apart. A total height of at lease fourty inches is therefore about right for heading back the whip. When the lateral buds are not reliable head the whip back to about twenty inches and develop the head as above from a new shoot."

"As to type of head, the open center or vase form top is now generally preferred for all varieties except possibly those that are especially inclined to droop, or those needing special protection against splitting or breaking down under load. The latter difficulty can be much reduced in any type of tree by having at least four to six inches of space between the points of emergence of the frame work limbs, or it can be eliminated entirely by a proper system of bracing within the top."

"Three limbs are sufficient for the frame work of a vase formed tree and a greater number than this is generally a nuisance later. It is usually best to start with four or five, however, in order to provide for the accidents that so often occur and also to retain a greater amount of foliage for the more rapid growth of the tree."

"No further training is necessary during the first season unless some of the limbs begin greatly to outgrow the others, in which case they should be pinched or headed back at their tips. In the case of the older nursery trees, already branched, this selection of the frame work limbs should be made at planting time, if satisfactory limbs are available; otherwisetrim them again to a whip and develop the head as above from the first season's growth in the orchard .

"Before growth starts in the second season, it is usually well to cut or head back at least some of the frame work limbs, especially those making the strongest growth. This is to keep the top coming on more evenly.

"Two good limbs, properly separated and pointing in the desired directions are all that are needed for each of the frame work limbs. This is done in the spring of the second year. These secondary branches should be handled about as indicated above for the primary branches, and they in turn should be expected to produce two or possibly three branches for the general frame work."

"The training work just described practically completes the general formation of the heads and it should be finished at least by the middle of the third season. After this the pruning should be reduced to a minimum until the trees come into bearing. Thinning out the denser places and crossing competing limbs and an occasional heading back of the extra vigorous branches that show signs of out stripping the others."

"After the trees begin bearing, somewhat stronger pruning may be done when needed, with the special object of getting more light to the fruit and assisting the trees tocarry their loads. The latter is accomplished by keeping the bearing wood low and well distributed through the tops, instead of at the ends of poles as is so often the final result of ill-advised work. This later pruning may well begin in the tops of the trees and work downward -- a practice which frequently results in the retention of lower or more central limbs that otherwise might be removed."

Lewis (17) and Gardner have recently issued a bulletin on training fruit trees. This system has been developed for arid and semi arid conditions. The low headed open center modified leader type of tree, on which drastic summer pruning is practiced, so as to very early develop a system of scaffold branches, has been evolved by experiments. They advise spacing the branches to avoid a weak head. For bearing trees a system of more or less severe heading back and thinning the branches has been evolved. This method of training may be advisable for the arid west, but for humid eastern conditions a more injudicious system of training could not possibly be devised.

Special Local Systems of Training.

The California system of training is well exemplified by Reeding (18).

"It is an invariable rule that all deciduous trees, outside of possibly walnuts and pecans, should be cut back to at least twenty inches from the surface of the ground after they have been planted. The following season the branches that have started from the main stem should be thinned out to three or four -- not more -- properly distributed so as to allow for their future

development and these varieties should have at least two-thirds of their summer growth cut off and all laterals should be removed, leaving only the frame work branches, which will eventually form the head of the tree. Above all things do not shorten in a lateral starting near the terminal point of any of the branches, as this will cause a bad crook to form in the tree. The result of this first year's pruning will cause the trees to make an immense growth and will also induce them to grow stocky.

"The second winter heavy thinning will have to be followed and the pruning should be done with the view of causing the frame work branches to spread out. After thinning half the growth of the current season should be cut off and again remove all laterals from the frame work branches. ---------- The third year from two to three laterals properly distributed should be allowed to grow from each of the main frame work branches but these laterals should have at least one half of their growth cut back.

"It is safe to assume that the trees in their fourth year have reached an age where at least a moderate crop of fruit may be expected and the head of the tree is now so well formed, that pruning to be followed in succeeding years is only to carry out the plan of continuing along the same lines as has been recommended for the trees. Failure to prune severely when the trees are young means that there will be a number of long spindling branches with practically all new growth at the tip ends. Should the trees bear a heavy crop the branches, will bend down under their heavy load, become sunburnt and even break off in some cases.

"The many advantages of this method of pruning are:

1. It makes a low headed stocky tree with a broad umbrageous head and well developed fruit spurs, and clothed with plenty of foliage, fully protecting the fruit from too much exposure in arid climates such as are experienced in California.

2. It enhances the carrying capacity of the tree, thus avoiding artificial props when maturing a crop of fruit.

3. It expedites the harvesting of the crop by rendering it more accessible to the pickers, thus economizing time and expense.

4. It prolongs the life of the tree by conserving its vital force and rendering it less liable to damage in the breaking of limbs and taxing its strength by carrying its fruit close in. "

TRAINING AND PRUNING

A great many fruit growers do not understand, or at least do not make a distinction between training and pruning. Keffer (19) tersely defines these two terms as follows:

"There is to be noted a considerable difference between pruning and training, the former word having the more restricted meaning. Pruning is the work of a single operation, or at most of a single year. Training is the work involved in bringing a tree or vine to its permanent form; it includes, therefore, several prunings, or as many operations as may be necessary to secure the desired form."

The question may be raised, "What is the value of training a tree. Why not plant the tree and then allow it to grow as it will?" We assume in answering this question that the object in planting the tree is the production of fruit for profit. By a judicious system of training, a tree can be so developed that it will produce more and better fruit than an untrained tree. The orchard operation of thinning, spraying and picking can be accomplished more cheaply and the net proceeds of the crop of fruit of the trained tree, other factors being equal, will exceed that of the untrained tree. In fact, there soon comes a time in the life of an untrained tree when the value of the crop decreases each year.

Nevertheless one method of training may be superior to another for a particular region, in giving the greatest net return for the work done. The Pacific Coast has proven that the very low, open centered, vase head, "sheared back each year", type of training is the only method that will profitably produce fruit under their conditions. But to follow such a method in the east, as sometimes attempted, will return smaller net profits to the grower, than a rational method suited to eastern conditions.

There are many factors that go to make up a successful system of training apple trees and they have to be modified to suit conditions in various parts of the country. These factors are (1) The work must be done with the least amount of labor possible. (2) The system must be adapted to the climatic conditions of the country. (3) It must facilitate orchard operations and keep down over head expenses. (4) It must produce the maximum amount of

highest quality fruit a tree is capable of bearing and permit the tree to bear at the earliest possible age.

There are a number of systems of training apple trees in use in the United States. For a particular region some must be superior to others. Have we in New England the best method for our conditions that satisfy the factors of a successful system of training as outlined above? At the present time the system as followed by the majority of fruit growers in New England, consists of heading the tree to the so-called vase type or globular type, with the first branch at eighteen to twenty-four inches from the ground and the last about six or eight inches higher. From four to eight branches are allowed to grow. These branches are cut back one fourth to one third their length. This spring cutting back is done for a few years in the majority of cases or until the tree bears, while some growers continue to head back indefinately. The bearing tree is sometimes hardly pruned at all, while in other cases it is heavily thinned and cut back. The writer believes that, while this system gives good results, it has a number of weaknesses and in the following pages attempts to prove his case against this method of training, and also presents a system, which he believes will give the best results in net profits under New England conditions.

Lack of Exact Advice on Training.

The number of well trained and pruned orchards is increasing, but even today the majority of orchards are not systematically pruned each year. In times of profit the orchards are well cared for, but during years of small crops and small returns or losses, the orchards are often absolutely neglected.

If training is essential for profitable fruit growing, what are the reasons that influence the practical grower to omit this work. Thacher (3), 1822, says, "There is no part of this management (orchard), perhaps so important and which requires more skill and at the same time is so little understood as the process of orchard pruning."

Beare (20), a modern pomologist, writes in the same view, "No other operation connected with growing an orchard

can compare in interest with pruning. It requires more knowledge, more experience and more thought than any other orchard work."

Proper training of apple trees is without doubt the most difficult and technical part of orchard work. In order to direct and guide the fruit grower, what specific rules and advice can he obtain from books, periodicals and Experiment Station Bulletins? The writer has read all the Experiment Station Bulletins that could be obtained, giving any advice on pruning, nearly all the modern books on Apple Growing and many articles in periodicals, society reports and state reports and finds that practically all the writers give the following advice, so far as the pruning operations are done.

1. Great importance of the proper formation of a strong frame work of the tree. Avoid crotches.

2. Keep the heads open.

3. Keep the heads low.

4. Cutting to inside and outside buds for growth control.

5. Take out crossing limbs.

6. Cut back tree to keep low or cut back over growing branches.

Nearly all advise:

7. Vase headed trees with three to six branches.

8. These branches cut back in the spring from one fourth to three fourths their length for two years or more.

Most of this advice is general, some of it is specific. It is little to be wondered at, that the practical fruit grower is often unable to successfully train his tree or that the results are not at all satisfactory.

The difficulty is the lack of exact methods adapted to all conditions operating in a region. The factors are those of climate, soil and cultural methods as they affect the different varieties growing in that

region. Lewis (17) says, "Again we must realize that soil, elevation and climate are factors which have a very close relation to pruning. Likewise, the variety question is always to be taken into consideration. For example the pruning of Jonathan in Southern Idaho, at an altitude of two thousand feet, on a silt loam, is an entirely different problem from that of pruning Yellow Newtowns in Western Oregon on a heavy soil at an elevation of one hundred feet."

In pruning the rules are specific so far as they deal with the plant physiology side of the effect of pruning, that is dormant and summer pruning; but general and meagre when they apply to the actual pruning technic as affected by the variable factors of climate, soil, varieties and cultural methods.

A System of Training should be based on Habit Of Growth.

The fundamental fallacy in all the present methods of training is that, under any method, all varieties are practically trained and pruned alike, in following out the particular system in use. Little or no difference is made as to the type of head, height of first branch, number of scaffold limbs, amount and character of pruning during different ages of the same variety and between different varieties.

Thomas Andrew Knight (1) said during the first years of the 19th century, "Each variety of the apple tree has its own peculiar form of growth; and this it will ultimately assume, in a considerable degree, in defiance of any art of the pruner." Thacher (3) writes about the same time, "Young trees differ much in their natural form and tendency and the mode of pruning should vary accordingly."

It has long been recognized that apple varieties differ greatly in tree characteristics, or as called, "habit of growth". Beach (21) describes the differences in habit of growth of bearing trees as follows: "Top: In describing the top the terms used, which are largely self explanatory, designate gradations from strong, very vigorous, moderately vigorous, or medium, to rather slow or weak growth. The form of the head as upright spreading as in Baldwin, wide spreading as in Rhode Island Greening, round headed as in Early Harvest, or upright as in Tetopsky. The

top is sometimes noticeably close or dense as in Fameuse or it may be open as in Haas, Lady, Gilpin, and Canada Reineth." King is also a good example of an open top tree. "Twigs: The new growth may be slender as in Rome or thick and stout as in Sutton. The twigs are said to be long jointed when the internodes, or the spaces from one bud to the next, are long; they are calledshort jointed when the internodes are short." A number of other factors such as number and position of twigs formed on the two year old wood, and differences in fruiting characters all bear on habit of growth.

In addition the habit of growth is effected by such external conditions as soil, climate, exposure and possibly the stock on which the tree is rooted. The effect of these factors is to modify or intensify vigor, so that in a system of training they are only likely to determine the amount of pruning. In some cases, however, the type of head and distance between branches may be affected.

Most writers on pruning recognize the difference in the habit of growth of the varieties and mention, in a general way, that varieties must be pruned with these differences in mind. But the writer has found very little specific advice given other than in pruning upright growers, to cut to outside buds and for spreading growers, to cut to inside buds. But no records or measurements of trees thus treated, giving the effect in spreading or prevent spread of trees, have been found. Observation would lead one to the belief that small results will be obtained from such practice. The facts of the case are that the varieties have not been systematically studied as to the relation between habit of growth and the training and pruning operations.

Any system of training to give the greatest success must take into account the habit of growth of each variety and the effect of all modifying factors, as acting on a variety, in a particular locality. This will not be difficult, if the variety can be observed growing under similar conditions in the locality.

HEADING AND HEADING

Types of Heads.

A number of different names have been given to the various types of heads. In reviewing the literature on training, the name most commonly used in each case, is the one selected to define the type.

There are four distinct types of heads to which apple trees are trained namely, the Globular type, the Open Center or Vase type, Modified Leader type and the Leader type.

The Globular type of head is often incorrectly called the Vase type in the East. To produce the Globular type, from three to six, or even more branches are allowed to grow, from the trunk in a space of from twelve to eighteen inches and ascending obliquely outward. Various limbs and laterals from these leaders fill up the top. When the tree is mature, the shape varies from roundest to spheroid. This is the most common type of head formed in the East. Photographs No. 1 and No. 2 illustrate this type.

The Vase type is developed in the same manner, except no foliage is allowed to grow in the center of the tree. The top is thus similiar to a vase in shape. This is actually a very rare type found only in the far West. See Photograph No. 3.

Lewis (17) gives the following description of the modified leader type. "In this type we start the trees exactly as though we were going to grow the center leader, but, begin ing from the second to the fifth year. the leader is suppressed." Photograph No. 4 illustrates in a degree this type of tree. From the ground to the first limb is 3 ft. The branches are distributed along a space of 3½ ft. There are seven scaffold limbs in all.

The Leader type is produced by allowing the trunk or leader of the tree to grow unchecked. The scaffold branches are located at intervals along this leader. A modification of this type is known as the two story tree. The scaffold branches arising in several groups along the trunk.

No. 1

Globular Type of Head

No. 2

Globular Type of Head

This is a twenty-five year old Baldwin tree. Height twenty-one feet. A good example of the globular tree with too many scaffold branches. Center bare of fruiting wood and shading of one branch by another.

No. 3

Vase Type Head

This tree is a true vase type tree and resembles a hollow, inverted cone or vase, the interior of the tree being free of wood. This tree is rearing its head well up from the ground and shows the difficulty of spreading this type. Notice the bare, pole like branches.

No. 4

Modified Leader Tree

This twenty-five year old Rhode Island Greening has a height of twenty-two feet.

Photograph No. 5 is actually of the two story tree, but will also do to illustrate the leader type. This tree contains ten scaffold limbs. The length of the leader from the first branch to the top is ten feet.

Height of Head.

A great deal of controversy has occured over the relative merits of high and low headed trees. Bailey (3) very clearly states the case as follows. "The relative merits of high or low heads for fruit trees are always in dispute. This controversy is partly the result of confusion of ideas, and partly of differing mental ideals and of varying climates. Two factors are chiefly concerned in these disputes—the question of ease of cultivation and the question of injury to the trunk by sun scald. It is the commonest notion that short trunks necessarily make low heads, and yet any one who can see the tree should know better. The number of trunks which a tree has does not determine the direction of the leaf bearing limbs. This tree (refering to an illustration) can be worked around as easily as it could be if it only had one long trunk. In fact, branches which start high from a trunk are very apt to become horizontal and droop. There must be a certain number of scaffold limbs to form the head. If these limbs are taken out comparatively low, they may be trained in an upright direction and hold their weight and position. If they are started out very high they will not take such an upright position, because the tree will not grow beyond its normal stature. High trained trees are often practically lowest headed."

The disputed point in the east has been too often over the height at which the first limb should project from the trunk, when in fact the whole controversy concerned the height of the bearing part of the tree above ground. There is nothing gained by having the first limb at 10 inches from the ground on one tree, and another bearing the first limb at 60 inches, provided the tops of both trees are the same distance above ground.

The advantages of a low head, meaning a low top are obvious and will not be discussed in this thesis.

No. 5

Leader Type of Head.

The photograph was taken of a twenty-five year old Baldwin tree. The height of this tree was twenty-one feet. Notice the open head, symmetrical top and good disposition of fruiting wood. Light can reach all parts of this tree.

The height at which the first limb should appear on the trunk as compiled from the recent Experiment Station Bulletins is as follows:

Paddock (1[illegible]) 20 inches, Hunson (22) 30 inches, Fisher (11) 12 to 18 inches, Jarvis (12) 2 feet for most varieties 3 feet for spreading varieties, Close (13) for low headed tree 12 to 18 inches, for high headed trees about 40 inches, White (23) 14 to 18 inches, Moore (15) upright growing varieties 18 inches, spreading varieties higher. Hedrick (14) 12 to 24 inches, Stewart (16) 25 to 30 inches. Lewis (17) under 20 inches.

This list indicates that the Experiment Station Pomologists recommend a tree having the first branch on the trunk not higher than two feet and in many cases lower. These are the heading heights for the so called low headed tree.

However, there is a great weakness in this arbitrary height, when applied to all varieties. Only two of the above Pomologists recognize the fact that the variety habit of growth must be considered in heading a tree. Trees with the wide spreading habit of growth of the Greening should have the first branch located on the trunk high enough to keep the greater part of the lower limbs off the ground. Such a height for the Greening would not be under 40 inches. 60 inches probably would be better and even with this height many branches would drop. Photograph No. 6 shows a Greening tree, with the first branch 40 inches from the ground. The advised height of less than 24 inches will be adapted for trees of the upright habit of growth. Photograph No. 7 is of a Sutton Beauty. This variety could have the first limb on the trunk at 12 to 15 inches above the earth and still not have its limbs spread on the ground.

There is absolutely no necessity to train trees with the branches so low, that they sweep the ground. Trees of the character of the Greening in the photograph do interfere with cultivation and some of the fruit is blemished by soil and is also difficult to spray.

No. 6

A wide spreading Rhode Island Greening.
Such a tree should have the first limb about
forty-eight inches from the ground.

No. 7

An upright growing Sutton Beauty. This tree can have the first branch under eighteen inches from the ground.

A tree may be so headed that while the extremities of the lower branches will be above the ground, the top will be so low as a tree with branches lower down on the trunk and the trunk can still be shaded from the sun scald.

The Globular or Vase Type of Head.

Since the Vase type is practically the same as the Globular type, the discussion will be confined to the latter, although observation on the Globular head will, in the main, apply equally well to the Vase head.

Practically all Pomologists and Fruit Growers advocate the Vase type of tree. Recently, however, Blake in New Jersey, Paddock in Ohio, and Lewis in Oregon have changed, and are advising the Modified Leader type. In reality, however, there are very few Fruit Growers, who consistantly train their trees to the true Vase type. The trees are started with 3 to 5 primary scaffold branches, the first branch occuring a foot to two feet from the ground and the remaining limbs distributed up the trunk in a space usually less than twelve inches long. As a general rule, in order to make the branches stocky, more or less heading back of the year old wood is practised until the tree comes into bearing. After this the usual, thinning out, and sometimes, heading back, comprises the annual training. The only advantage claimed for the Vase or Globular type, is that by having all the scaffold limbs arrising from the trunk at a distance not above 30 inches from the ground, a lower head is obtained, than in the case of a tree trained to the Leader type. Actually, however, this type of head is not lower than the Leader or Modified Leader tree, when each type is treated alike, as having the first branch arrising at the same distance from the ground, and the repressive pruning of the top the same. In other words, the top of a Globular tree has to be pruned to keep it within bounds as in the case of a Leader tree.

On the other hand the Globular tree has the following faults not found in the Leader type. It is structurally weak. Also due to the oblique position of the main scaffold limbs there is a poor distribution of fruiting wood, which makes pruning difficult and proping necessary, under a load of fruit to prevent splitting down of the scaffold branches.

The indictment of being structurally weak is admitted by even the most ardent advocates of this type of training. Practically all writers, who advise this method of training, mention this fact and give various methods for bracing and strengthening the scaffold limbs. This breaking down of the scaffold limb at the point of union with the trunk is due to two reasons. First, the branches grow outward in an oblique direction from the trunk. With a load of fruit the branch acts like a lever, with the fulcrum at the trunk. The result is that a great strain is placed at the trunk which often results in the splitting down of the limb at this point. The second reason is that the branches are spaced closely together and often make an acute angle with the trunk. Thisfact tends to produce a weak union and splitting results. Such splitting in a Vase pruned tree is a serious occurance. This type of tree is usually composed of from three to six scaffold limbs each in itself making up from one third to one sixth of the top, as the case may be. Thus if one of these scaffold branches is broken down a fruiting part of the tree is lost, corresponding to the proportion taken up by that branch. In the case of old trees such a fruiting area cannot be restored, while in young trees it is often difficult to repair such damage. The photographs used to illustrate the necessity for wide angles and separation of primary scaffold branches, illustrate this structural weakness of the Vase and Globular Head.

The natural tendency of an apple tree is to develop and maintain a leader. In the Globular type each scaffold branch endeavors to become a leader. There are thus from three to eight limbs striving to push upward and competing for space in the top. To keep these limbs from crowding and producing crossing and rubbing branches compels the grower to spend much time in pruning. In addition where over four or five scaffold limbs are allowed to grow there will occur long leaders that are unbranched for some distance from the trunk. This is one ofthe chief objections held by Professor M. A. Blake of the New Jersey Agricultural College to the Globular tree. Inphotograph 8 used to illustrate the Vase type of tree, notice the long bare scaffold limbs in the center of the tree. In fact this propensity of the Globular tree to produce long bare scaffold limbs, with a dense mass of twigs at the ends has earned such limbs the title of "Cow tailed branch."

A typical Gobular tree when twenty five years or older often consists of a number of such "Cow tailed branches" with the interior of the tree bare of leaf and fruit and the perifery of the tree consisting of a mass of tangled branches and twigs where the fruit is borne.

The Globular tree does not give the best arrangment of the fruiting laterals and twigs. In this type of head most of the primary scaffold limbs extend obliquely from this trunk. On these large limbs are a number of smaller branches, arranged about the larger limbs and the majority of these sub-scaffold branches also extend obliquely outward, they in turn have many laterals aranged in the same way. The result is that each scaffold limb consists of a ramification of branches, laterals and twigs extending obliquely outward in the general direction that the branch is growing. When the twigs becoae laden with fruit, the laterals and branches are bent downward. But due to the fact that the main limb and many of its branches and laterals are growing obliquely outward in the same direction, this whole mass of branches must bend over in this direction. That is, as a rule a branch growing on the inner side of a scaffold branch, cannot bend backward towards the center of the tree, but must bend forward to the outside. This lapping over of one branch, with its lateral fruit spur growth, over another such fruiting group, may be compared to the spreading of the leaves of a book, when it is opened. Study the photographs and notice how the fruiting branches spread over each other in the manner described. This fact explains the reason why it is often so difficult to grow fruit on the inside of a Globular headed tree. That is, the branches shade each other and keep the light from the center. This oblique direction of growth is responsible for the necessity of so much propping of branches when the tree is laden with fruit.

Such a tree is a puzzle to prune, due to the fact that pruning is usually done in the spring, when the branches are not bowed down with fruit and it is difficult to know just what branches to thin out.

Many fruit growers have too many scaffold limbs to the head of a tree. In the Globular type all these troubles are intensified by having a large number of scaffold limbs. In addition some of the limbs in the center of the tree will not be branched, when there are a number of scaffold branches, with but three scaffold branches, the tree develops three great leaders. These leaders carry most of their branches on the outside of the tree as described above. Inside the tree will be formed only a few weak branches on any of the leaders and these that are formed will be struggling upward to the light. Thus each leader will consist of a number of branches on the outside extending in the same general direction and the inside of the limb will be practically bare. For example, see photograph No. 2 and 8.

The great necessity for low headed trees arose in about 1900, with the advent of the San Jose scale and the revival of interest in fruit growing. Patrick Barry, Warder and other prominent writers on fruit Growing had advocated the Vase and Globular type in their writings, so that all over the United States the young trees planted since 1900 have been headed in this manner. It is time that the Globular tree, as trained today, is a lower tree than the Leader tree of the era prior to 1900. This is not due to any inherent factor in this type to be low headed, but solely to the fact that the first branches are trained off the trunk nearer to the ground and repressive pruning of the top practiced. Bailey (9) in discussing the principles of pruning says, "A pruned plant tends to resume its natural habit." and "In whatever way or however much the plant may be pruned, it immediately makes an effort to regain its former or habitual shape and behavior." Unless repressive pruning is constantly practiced in the Globular tree, certain of the scaffold branches will grow upright and a tall tree will result. In the Leader or Modified Leader type if the heads are formed at the same distance from the ground and pruned in the same way, the trees will be no taller than the Globular head. Measurements made in the Massachusetts Experiment Station orchard on all these types of heads substantiate this statement.

No. 8

Globular Tree

This tree is a good illustration of a globular headed tree in showing the result of starting the tree with too many scaffold branches. Notice that the branches are developing a "cow tailed" character, the fruiting wood being carried in a tuft of laterals at the end of the branch. The shading effect of the branches due to their oblique growth is noticeable.

Measurements on trees in the Experiment Station Orchard.

In studying an orchard planted in 1890, on the grounds of the Massachusetts Experiment Station, the writer was surprised to find a number of Leader and Modified Leader trees in addition to many Globular headed trees. To compare these types of heads a number of measurements were made; The varieties were, Baldwin, Greening, Russet and Gravenstein, which gives a excellent choice in comparing the heads since these varieties differ greatly in habit and growth. For experimental purposes the orchard consists of five plots of twelve trees each. Plot No. 1 has received 3½ cords of barnyard manure No. 2 2000 lbs. of Wood Ashes, No. 3 Nothing, No. 4 600 lbs. Bone Meal, Muriate of potash 200 lbs, No. 5 600 lbs. Bone Meal and 400 lbs. low grade sulphate of potash. The fertilizers were applied each spring. Some of the trees are diseased and were not included in the measurements.

The trees were measured with a 20 ft. pole marked off in six inch spaces. The distance of the first scaffold limb from the ground was measured. From the first scaffold limb to the last scaffold limb gave the length of the trunk carrying the scaffold limb. The height of head was measured from the ground to the top of the current year's growth. The spread of the trees was formed by averaging two measurements, taken at right angles to each other at the trunk and extending from the tip of the branches at one side to the tip on the other side. The leader and modified leader trees in this orchard might be called accidental leaders. In heading these trees, evidently four to six limbs were saved for scaffold limbs. In some cases the central one developed into a true leader or was checked at four or five feet forming a modified leader.

Note. 1

For complete data on this orchard see the 22d Annual Report of the Massachusetts Agricultural Experiment Station Part II, Page 10. Jan. 1910.

NOTE 2.

For illustrations of the various types of heads as formed in this orchard see photograph of Vase headed tree on page 20 Modified Leader tree on page 20 and Leader tree on page 21.

TABLE I

Average Measurements on Massachusetts Experiment Station Orchard

Type of Head	Height of Head	Spread of Branches	Lowest to Highest Branch	Number of Limbs	Number of Trees
Leader	19' 10"	25'	8' 6"	9	10
Globular	19'	25'	9"	5	30
Mod. Leader	18' 3"	27'	3' 1"	7	14

Individual Measurements of Trees in the Experiment Station Orchard

LEADER TYPE.

	Ground to first limb	first limb to last limb	Number of limbs	Height	Spread	Plot No.
Baldwin	3	10 6	13	21	28	1
"	3	7 6	8	20	29	5
"	3	7 6	8	23 6	29	5
Gravenstein	3 6	7 6	10	17 6	23	3
"	3	7	10	18 6	22 6	4
"	3	12	5	21	21 6	5
"	3	12	7	20 6	23	5
Roxbury	2	8	13	19	30	4
"	3	7	10	18 6	27	4
"	3	6	8	18 6	25	5

GLOBULAR TYPE.

	Ground to first limb	First limb to last limb	Number of limbs	Height	Spread	Plot No.
	3'	0"	5	18' 6"	31'	2
Greening	3	6	6	17	27	
	3	6	5	20	29 6"	
	3	0	5	17	25 6	3
	2 8"	1' 4	5	18	23	4
	3	1	4	18 6	26	
	3 4	0	2	19	27 6	5
	3	3	5	18 6	24	4
	3	6	6	17	27	2
	3	6	5	20	29 6	2
Roxbury	3'	0"	5	19' 6"	24'	1
	2	1' 6	5	19	28	1
	3	10	7	17 6	26	5
Baldwin	2' 4"	8"	6	22	29	1
	2 4	0	5	19 6"	25	1
	2 4	1'	5	21	27	2
	3	0	5	20	24	2
	2 6	0	5	20 6	22 6"	2
	3	6	5	17 6	21	3
	3	1 6	6	21	26 6	4
	3 4	4	4	18	20 6	4
	3	0	8	21	28	5
Graven-	3	2' 6"	6	18' 6"	21	1
stein	3	1 4	6	16	24 6"	2
	3	10	5	20	25	2
	2 6"	2	6	20	23	2
	4	4	4	19 6	24 6	3
	3	6	5	18	17	4
	3	1 6	6	20 6	23 6	4
	2 6	0	3	22	24 6	5

MODIFIED LEADER TYPE.

	Ground to first limb	First limb to last limb	Number of limbs	Height	Spread	Plot No.
	2' 6"	3' 6"	10	20'	32'	1
Greening	3	3	6	20	32	1

MODIFIED LEADER TYPE. (Continued)

Greening	3'		3'	6"	7	22'		31'		1
"	3		2	6	7	18		29		3
"	3		5		11	17	6"	29		4
"	3		3	6	7	19		27	6"	5
Roxbury	3		3	6	9	17		29		1
"	2	6"	3		6	16		26		2
"	3		2	6	9	16		25	6	2
"	3		2		8	16		27		2
"	3	6	2	6	6	13	6	25	6	
Baldwin	3		1	6	6	19		23	6	3
"	3		4		5	18		22		4

TABLE II.

Numbers of trees in each type of head according to plots of the experiment.

	Plot I. Manure	Plot II. Nothing	Plot III. Nothing	Plot IV. Bone meal & muriate of potash.	Plot V. Bone meal & low grade of sulphate of potash.
Leader	1		1	3	4
Globular	5	7	6	6	4
Mod. Leader	4	3	3	2	4

TABLE III.

Number of trees of each type arranged according to variety.

	Greening	Roxbury Russet	Baldwin	Gravenstein
Leader		5	4	4
Globular	7	5	9	8
Mod. Leader	7	4	1	1

TABLE IV.

Average height of each variety as found in the various plots.

	Plot I.	Plot II.	PlotIII.	Plot IV.	Plot V.
Greening	20'	18' 6"	17' 6"	18' 3"	18' 3"
Roxbury	19	16		18 99	18
Baldwin	20 10"	20 6	18 6	19 9	21 6
Gravenstein	18 6	18 8	18 6	19 8	21
Average for all	19.6	18.4	18.2	19.1	19.8

Table No. I shows that these trees are on the average about the same height and spread. Comparing the trees of one plot with another according to variety, as in Table No. IV there is a slight difference in height and spread. That is, the trees in plots No. II and No. III are about one foot lower in stature than the trees of the other plots. Table No. II, however, shows that this difference, if it effects the figures to any extent, will work in favor of the Globular type, as there are fifteen Globular trees in these two plots against seven of the Leader and Modified Leader trees. Taking the measurements of these trees

as influenced by all the factors of variety and soil treatment that might effect growth, it is considered that they represent a fair comparison of the results of training trees to the Globular, Modified Leader and Leader types of Heads. Under these conditions, giving the same treatment to each type, it is evident that the height of the tree is not affected by the type of head.

The Leader Type of Head.

The writer of this thesis is firmly of the opinion that the best type of head for New England is the Leader type.

Only two objections have been raised against this system of training, namely, that the trees grow too tall and that blight having developed on the leader, may destroy the tree.

The objections to the Leader tree growing too tall is well founded, but in most cases this towering growth is due to close planting and high heading and will be found in any type of head grown under similiar conditions. As has been mentioned before the Leader tree will be no higher than the Vase tree if grown under similiar conditions and with the same treatment. The essential point in preventing the Leader from growing too tall is to give the tree plenty of room to grow in width, for this type naturally makes a big tree.

For New England conditions, the danger of the tree being destroyed by Fire Blight is negligible since this disease is only found on the current years wood.

The advantages of the Central Leader type are, that it gives a stronger head than any other type, the fruit is distributed to the best advantage and the tree has the largest possible bearing surface and finally, the Central Leader is the natural habit of growth of the apple tree and it is the easiest to prune.

The strength of the head of a Central Leader tree is due to the obtuse angles the limbs make with the trunk and that the limbs are distributed along the leader enabling them to form a pronounced collar adding great strength and rendering it possible to split under the heavy load.

This type of head has a larger bearing surface and offers a better distribution of fruiting wood than the Globular head. The greater bearing surface is attained through the additional primary scaffold limbs and also through the greater ease with which the tree is spread in width. The point may be raised that the additional primary scaffold limbs are only secured through increased

height of the tree. It must be kept in mind, however, that the scaffold branches of the Leader tree, especially the upper ones, arise at right angles to the leader and droop downward. In this way the actual fruit carrying area of these branches is much lower than the position of the limb on the leader. The possibility of widely separating the primary limbs of the leader tree and the opportunity for these limbs to droop downward without greatly shading the limbs below is the important factor in giving the maximum amount of room for the distribution of fruit. A properly trained Leader tree is open to the light, so that the interior of the tree is able to develop fruit buds and color the fruit. The writer wishes to strongly emphasize these facts of increase in crops of better color, which can be secured thru training to the Leader system.

The natural tendency of all apple varieties is to grow a central leader about which the scaffold branches radiate. This point is of great importance in training apple trees for when the training operations are carried out in conformity with the trees growth inclination better results will be secured than if continual opposition is encountered by the tree in its development. In a recent issue of the Rural New Yorker, Mr. A. C. Reed (24), a prominent apple grower of Western New York says, "The Leader system gives a tree of the natural shape. We are not compelled all the time to fight the natural tendencies of the tree growth but only to direct it."

Due to this fact the leader tree is easier to prune and also requires less pruning than other types of heads. For the Vase or Globular tree good judgment must be exercised in training to this type and considerable pruning done to maintain the proper balance between the scaffold branches and in keeping the head open. In the Globular and also the Modified Leader types, several of the scaffold limbs are sure to compete with each other as leaders. The pruning of such limbs is difficult, since branches cannot develop freely about the scaffold limbs, especially on the sides towards the other competing limbs and great difficulty is experienced in keeping the head open and the centers filled with non-interfering bearing wood.

The Modified Leader Type.

The Modified Leader type is a great improvement over the Globular type, since the branches are well spaced, thus giving a strong frame work for fruit bearing. Although the writer has not had the opportunity to study a number of trees of this type, he is of the opinion that probably the only objection that could be raised to the Modified Leader tree would be the fact that some of the scaffold limbs would compete with each other as leaders. Such a condition would tend to make the training operations more difficult than in the Leader tree and possibly not giving as good distribution of fruiting wood.

At any rate the fruit grower will make no mistake in adapting this mode of heading, for good results should be secured through its use.

FUNDAMENTAL PRINCIPLES IN FRAMEWORK FORMATION.

Ages in the Life of the Apple Tree.

In the growth of an apple tree from the bud or graft until it has ceased to be a profitable member of the orchard and is cut down there are three distinct ages. These divisions are based on the training treatment given the young tree and are: (1) The Nursery Age, (2) The Formative Age and (3) The Fruiting Age.

If the fruit grower purchases his trees he has no concern as to the methods used by the nursery man in propagation of the trees. All that he is interested in is that the trees be true to name and well grown, with a good root system. The methods of budding or grafting, whole or piece root are of no importance in the ultimate growth and fruit producting capacities of the trees provided they are of the same size and vigor. It is, however, of concern to the nursery man as to propagation methods, for certain methods will produce larger and better trees in the same time than others.

The Formative Age is the most critical age in the tree's life. During this period, the framework, on which the future crop will be borne, is developed. It will be difficult, if not impossible to rectify mistakes made at this time. At the start a choice has to be made as to the type of head. If a mistake is made here it is practically impossible to change the type, when the tree has entered the fruiting age. The writer is strongly of the opinion that for many varieties the Leader type of tree is gaining favor in the East. For other varities the Modified Leader type may be chosen. Other important factors in training, which must be considered, are discussed in the succeeding chapters.

The Fruiting Age of the tree usually starts from the fourth to the tenth year, depending on the variety and the method of training. This period is overlapped by the Formative Age when the trees are trained to the Central Leader type. This is due to the fact that the leader demands attention, when the lower branches are fruiting. The age may also be subdivided into two periods, the first being that of vigor, with the production of maximum crops of fruit and the second that of old age, when the crop producing energies of the tree have begun to wane.

The Ideal Apple Tree.

In all training operations the first grower must not only understand the principles of training, but should also have an ideal tree in mind, the realization of which, all pruning operations should be directed.

For New England conditions such an ideal tree would be one having the largest possible bearing surface with a framework strong enough to bear maximum crops of fruit. The head of the tree should be so constructed that light would be admitted to all parts of the tree to develop fruit buds, color fruit and to check fungus deseases. Such an open top would also facilitate spraying, thinning, picking and pruning and in this way would permit the production of the finest quality fruit at the lowest possible cost.

To achieve such an ideal, certain fundamental factors in the formation of the framework of the tree must be thoroughly understood and put in practice with the planting of the tree and a logical system of training must be adopted and consistantly carried out during the life of the tree. These fundamental factors will be discussed under four heads, first a general discussion of certain principles of heading, second, the proper development of the tree in the Nursery, third, and fourth, the principles underlying the training during the Formative and Fruiting Ages respectively.

Scaffold Branch Angles.

The importance of having the scaffold limbs emmerging from the trunk, with a wide angle, has been overlooked by fruit growers. The first reference to angles that the writer has found, is by Shepard (25) who writes in Better Fruit in 1910 as follows: "Prune for sturdy, strong lower limbs rising at an angle of from 50° to 60°." Benson (26) in an article on pruning trees in the same periodical advises as follows. "The term, "avoid forks," is often used in pruning, though the writers fail to explain how to proceed in order to avoid these forks. When you start the tree it should be headed after planted at the desired height." "Now this tree after starting will sometimes throw out sufficient branches to

form a good head the first season, while again at other times it will only throw out two, three or four branches which all make sharp crotches or forks and all buds below these will only make leaf buds. Many growers make a mistake right here. In starting new trees they will proceed at once to rub all these buds off, and the result is they have a very poor headed tree, with a lot of sharp forks. In order to overcome this you should let all the buds grow the first year after planting and if nothing but crotches are on your trees cut all of these crotches out the following spring when the tree is pruned and leave your center leader. By so doing the dormant buds below will be forced out the second year and make strong branches, which will grow out in more of a horizontal shape from the main stalk. These make very strong branches, as you may bend them clear to the ground without breaking them off from the trunk."

The objections to having the scaffold limbs appearing on the trunk with an acute angle, is that the union between the limb and the trunk is structurally weak and is quite likely to split down under a load of fruit. Also when the primary scaffold limbs develop with narrow angles, they extend in a more or less upright direction, so that the branches are close together, producing a crowded top. Such a direction of growth of the primary limbs is opposed to the development of a wide spreading head, which allows for the best development of a free and open fruit spur system.

That these objections are real is attested by experience and observation of bearing trees, where the scaffold limbs have developed in this manner. More (27) cites the instance of a large orchard that was carefully handled in every way, but failure to properly head the trees, resulted in such a large number having been split at the head, with the first heavy crop that the grower was discouraged.

In an orchard of thirty-five acres about forty years old, not over two miles from this college the owner estimated that twenty percent of the trees had the scaffold limbs braced, due to splitting down at the trunk. The photographs clearly show this condition. The objection may be raised that this splitting is due not alone to the angles being narrow, but to the fact that the scaffold branches are crowded together. This objection

may carry some inlight, but the fact remains that splitting only occurs when a narrow angle is present. Also, even if the branches are started at the same point, the heads will be strong, provided the angles are wide. The great number of such orchards having trees headed in this manner, that have not split down under the loads of fruit, is proof enough of the statement. Notice the wide angled scaffold branch growing to the ~~right~~ left in photograph No. 9. This branch shows no evidence of splitting. Compare this with the two branches in photograph No. 10 that are narrow angled and are cracked at the base.

Experiments were carried out on Nursery trees the past year to study the growth of scaffold limbs with reference to the factors influencing the development of angles. The results are given in another chapter in Experiments on Head Formation.

External observations on old trees shows that a wide angle forms a swelling or colar at the point of emmergence at the trunk. This swelling extends completely around the branch, being thickest at the trunk and extends a few inches in a tapering manner to the branch. On the other hand a narrow angle limb does not have this collar and at the apex of the angle the tissues appear to be pushing against each other, with the result that a crash is present. Figure No. 11 illustrates the collar of a wide angled limb. Longitudinal sections, but along the same plane made by the trunk and the limb, were made of small twigs of both narrow and wide angled branches. These sections were examined under the microscope to determine the structure of the union between branch and limb. Figures Nos. 12 and 13 illustrate the type of wide and narrow angled limbs examined. Examinations of young trees reveal the fact that the strength of the limb at the trunk is determined the first year by the angle made by the growth of the limb. The narrow angled limb as illustrated breaks readily at the trunk while the wide angle limb requires a very much greater stress to tear it from the trunk. Even at this early age the crash or division between the limb and trunk of the narrow angled branch has appeared.

Spreading the Scaffold Limbs

A proper spread to the scaffold limbs is important in the formation of a good head. This spreading of the primary scaffold branches ie one of the fundamental

No. 9

Splitting of branches due to narrow angle.

A well defined collar may be noticed on the wide angled branch at the left. Such branches cannot break down at the trunk.

No. 10

Bracing of the scaffold branches to prevent destruction of tree.

No. 11

A bad crack in a globular headed tree. Separation of branches on a leader would prevent such cracking.

principles to be kept in mind at the time of the selection of these limbs. The future head of the tree must be kept open so that the fruit carrying wood on each primary scaffold limb may have abundant room to grow unrestricted by its neighbors. In ~~Figure~~ Photograph No. 14, due to severe cutting back of the primary scaffold limbs at planting the growth was upward. Each of these limbs have been compelled to develop their sub-scaffold limbs in a small space, with the result that the head of the tree becomes chocked with branches. Those sub-scaffold limbs growing on the inside of the tree are dwarfed and either never develop or in time have to be cut out due to crowding. The successful sub-scaffold limbs are the ones growing on the outside of the primary limbs, or else in the top. But those lower down will in time be dwarfed by the upper or more vigorous sub-scaffold limb, with the result that there is a tendency for the fruit carrying wood to develop high in the top, producing a high headed tree. In this tree the fruiting wood is about six feet from the ground. If for the first few years of the tree's life each primary scaffold limb had been compelled to grow outward, giving a wide distance between each limb, the tree would have been lower headed and a good distribution of fruiting twigs would have been obtained.

The only way the bearing surface of a tree may be increased, if the tree is prevented from growing beyond a certain height, is by compelling it to grow in width. By starting the primary scaffold limbs with a wide angle and keeping them growing outward for the first few years, such a spread is more easily obtained later in life. The primary limb itself continues to spread and as its fruit bearing surface increases in area the limb grows in size and is thus able to well hold up the crop. With the primary limbs growing upright, the spreading limbs must be developed from the primary limbs and these secondary limbs will practically all be placed on the outside of the main limb. This gives a distribution of fruiting wood and the extreme drooping of the limbs under a load of fruit.

Hedrick (14) says, "Whatever the form, care should be taken that the lowest branches are longest, so that the greatest possible leaf surface will be exposed to the sun and light." To have these lower branches the longest and not interfere with the development of the upper limbs, it is essential that they grow outward from the start.

No. 12

Narrow angles in young trees.

Such angles as these if allowed to develop into scaffold limbs on the young trees are certain to be weak and will often break down under a load of fruit. Such limbs should be pruned off.

No. 13

Nursery tree with wide angled limbs.

This tree presents a good example of the wide angles to be sought on a young tree at planting. Such scaffold limbs will never break down at the trunk.

The habit of growth of the different varieties play an important part in obtaining a wide spread to the limbs. Varieties such as Rhode Island Greening and Nero make a naturally wide spreading tree. If these varieties are started with wide angled primary scaffold limbs, no more attention need be given the trees in order to make the limbs spread. In fact after the first year it is well to encourage an upright growth, for when the trees have fruited a few years, the limbs will naturally assume a wide spreading direction of growth. Sutton and Spy and naturally upright growers and care must be taken to keep them spreading at all times. This is a difficult proceedure, but can be carried out, in a measure, by starting the primary scaffold limbs at a wide angle. In the chapter on A Method for Training Apple Trees, the methods for spreading these varieties will be discussed in greater length.

Separation of Branches.

One of the most essential requirements for the framework of a tree, is that the primary scaffold limbs shall be widelyseparated. Within the past few years, Pomologists and Fruit Growers have recognized the fact that to crowd the branches into a small space on the trunk, incurred the risk of splitting at this point, when the trees were laden with fruit. This fact is responsible for the rise of the Modified Leader tree in the past few years. The photographs of the trees used to illustrate the effects of narrow angles are all of trees, on which the limbs were crowded into a small space. There is great danger that such splitting will occur under such circumstances, but usurally only when the scaffold limbs make a narrow angle with the trunk. This point is discussed in the next chapter. Lewis (17) says, "The farther apart they (the scaffold limbs) are spaced the stronger and better will be the trunk and the better the tree obtained." Wickson (27) states that, "A vastly stronger tree is secured by starting but 4 or 5 branches from the low trunk and letting them emmerge from different sides of the stem and at different levels. Thus each main attachment to the stem has abundant room and the wood enlarges symmetrically and solidly."

No. 14

The scaffold limbs of this tree were cut back to stubs at planting. Note the upright growth of the four scaffold limbs and the choked condition of the head.

Stewart (16) advises 12 to 15 inches on the trunk for the development of branches, tree of three branches would give six inches between each branch. Many writers of recent bulletins and current literature on training, who advise that the branches be well separated, make the mistake of cutting the whip back so short that it is impossible to properly separate the branches. A number of bulletins in which the advice is given to separate the branches, illustrate the method of training advised with a tree having branches practically arising at the same point. See Foot Note.

The advisability of having the tree with well spaced branches, to insure a strong framework, is only one of many reasons for such practice. It seems surprising that practically all Pomologists have apparently not given thought to the other important factors involved in the production of high quality fruit, through a wide separation of scaffold limbs. These factors are the production of more fruit of higher quality and reduction in the cost of labor.

In the East, due to cloudy weather during the ripening season and a lack of bright sunlight, it is necessary to pay more attention to the open head, than in the West where there are many intensely bright days. The method used in the East for keeping the head open is to annually thin out the top by dormant pruning. This takes time, increases the cost of production, is sometimes never or poorly done and often, due to dormant pruning, the top quickly fills up with twigs, so that in a dense headed tree the light is largely shut out by the middle of August. In photograph No. 15 notice the dense head of the tree. The fruit in this tree is all on the outside.

By having the scaffold limbs widely spread on the trunk and properly arranged, high quality fruit can be produced in greater quantity at less cost than where the limbs are crowded. This statement is based on the facts that sunlight is essential for the production of leaf and fruit buds, to color fruit and to check the growth of fungus diseases and also that a deeply colored red apple, free from blemishes brings the best price in the market. Funk (28) says, "A very common error in top formation is to have the branches too close to each other, so that when they come to bear the wood, foliage and

Foot Note.

(Pennsylvania Exp. Station Bulletin No. 125, page 117. The tree illustrated with these branches show very little space between them.

No. 15

Dense top caused by failure to separate branches. The interior of this tree is bare of fruit, which is found in the outer portion of the top. Light cannot penetrate to the center of the tree to develop fruit or leaf buds.

fruit on the interior are so excluded from air and light that they all suffer, the fruit is imperfect and the spurs become feeble and gradually die."

To produce such high quality fruit the scaffold limbs should be separated 12 inches or over on the trunks of varieties developing many long fruiting twigs, with large leaves and at least 8 inches for varieties developing short twigs. For the many long twigged varieties, this means that with the limbs separated the minimum distance of 12 inches, the fifth limb will be four feet above the first limb, if the primary scaffold branches have been properly arranged about the trunk. For the short twigged varieties the fifth limb will be 32 inches above the first limb. The result is that each scaffold limb has abundant room to develop a normal fruit spur system. Such wide separation of branches admits light and air to all parts of the tree, the fruit colors readily in bright light and during cloudy weather will obtain the maximum color possible under the existing conditions. Fungus deseases, that thrive in a damp atmosphere are checked, since the light reaches all parts of the top and the air can circulate freely.

The wide separation of branches prevents the retention of too many scaffold limbs no matter what type of head may be adopted. Photograph Nos. 16 and 17 are of a yellow transparent and a yellow Ballflower tree. In each case seven or eight branches have been crowded together into a small space on the trunk. In a few years these limbs are going to be so crowded that some of them will have to be removed. Cutting out large limbs is bad practice and should always be avoided by proper selection of limbs the first year the tree is planted. In these trees the tops are so dense that the interior branches can only form fruiting wood near the tops. Such a condition leads to the production of fruit only in the outside shell of the tree with the interior bare of fruit.

The cost of labor operations are reduced. The pruning instead of being done from the outside of the tree will occur along each scaffold limb. This pruning will consist of a thinning out of crossing twigs and should be of small amount, depending largely on the vigor of growth of the variety. The work can also be done more efficiently, since it is often very difficult to know just what branches

No. 16

A young Yellow Transparant tree with too many scaffold branches. Notice the upright growth of the branches due to cutting back at planting. When this tree is a few years older some of the branches in the interior of the tree will have to be cut out.

No. 17

Yellow Bellflower tree. Notice the poor arrangement of scaffold branches. This tree needs a thinning of the top. The tree is bearing but no fruit is carried in the center of the top.

or twigs to remove when standing on the outside of the tree composed of a dense mass of branches and twigs in the perifery of the tree. As a rule the pruner with the twiggy varieties does not thin enough in the spring, when the trees are bare of leaves to give a head that is open enough, and on the other hand should he do so, the tree is thrown out into wood growth and by September the dense condition is as bad as ever. Summer pruning is left as a means of thinning the top, but the work is not easily done and its advisability is questioned for the most.

With an open top spraying can be done more quickly and efficiently than where the top is dense. By having the branches widely separated the operator can handle his spray rod so as to spray along the branches from the tip to the center thus doing the work more quickly and efficiently and using less material.

Thinning and picking the fruit is facilitated by a wide separation of branches, which permits the fruit to develop on laterals and twigs carried by branches, that are placed along the primary scaffold limbs from their extremities to the trunk. The laborer can do the work more efficiently and quickly when distributed in this manner, than in the case where the fruit is borne in a dense mass of twigs and branches at the outside of the tree.

Batchelor and Goodspeed (33) reports as follows for vase formed trees having branches closely together. "The fruit on the unpruned trees was poorer in color than on the Winter and Summer pruned plots. In 1914 the unpruned plots had 70 percent as much color as the other plots." "The size of the fruit was largely equalized by thinning the several plots. It cost about 25 percent less per tree to thin the pruned trees than the unpruned ones. The actual price being 20 cents and 15 cents respectively. As a means of thinning the fruit and improving the color by opening up the dense growth of the tree, the moderate pruning is advisable." If these trees had had the scaffold limbs widely separated the probability is that the limbs would have developed without much crowding and thus less pruning would have been necessary. This experiment shows the necessity of an open head to produce better color and to reduce the cost of thinning.

This system of spacing the scaffold limbs is especially well adapted for planting trees on steep-hillsides. With the Vase form of head the branches that point

up the hill drag on the ground, while the branches pointing down the hill are often quite high in the air. By spacing the primary scaffold branches for a hill-side orchard, the first branch on the trunk should grow down the hill, the next two should point across the slope and the fourth, which may be placed on the trunk at a good distance above the first three, should point up the slope. In this way the fruiting wood of the tree is carried off the ground, it is accessible for pruning and the fruit is easily picked.

Nursery Age.

The important points to be emphasized in purchasing trees are that they shall be guaranteed true to name and that the Nursery firm will make good the loss or damage within ten years if the trees prove not true to name, also that they shall be healthy and properly natured.

A strong root system is often of the utmost importance. This should consist of a number of roots, about the size of a lead pencil, well distributed about the crown. A tree with two or three large roots or many small fiberous roots should be rejected.

Nursery men sell trees by size, but also state the size of the top.

The usual standard in grading trees is as followe:

	Age	Weight	Price. Each	Total
Largest size	2 yr	5 - 7 ft:	$.20 - $.35:	12 - $25
Medium "	2 "	4½ - 6 " :	15 - 25:	9 - 18
Smaller "	2 "	4 - 5 " :	10 - 25:	7 - 13
Largest "	1 " whip	3 - 6 " :	15 - 25:	10 - 18

These prices were taken from Nurserys catalogues for the season of 1916. The prices vary greatly for the same size of tree, which so far as a purchaser could ascertain from any of the catalogues, were propogated from the best stocks and grown under ideal conditions. The higest priced trees in the above compilation, which also were the lowest in the standard as to size, were grown by a middle western nursery man, who advertises extensively.

Of the above trees only the largest size 5 - 7 ft. or the medium sized 4½ - 6 ft. trees two years old or the largest whip 5 - 6 ft. should be purchased. There is little choice in any of the above, except the medium sized two year old and the one year old whip are cheaper than the largest sized two year old tree. The important point, however, is to secure the framework of the tree in the

shortest possible time and by using the larger sized trees, it is possible to save from one to two years, than if the smaller size trees were purchased. In addition it would be inadvisable to purchase the smaller trees, since they are evidently the least vigorous of the trees grown.

The proper planting has an important bearing on the future success of the tree. Pickering (2) says, "Anyone who can double the amount of branch and root growth in the first two years is making possible larger crops at an earlier date."

In the training method to be outlined it is essential that the tree should make a vigorous growth the first year. In order to insure such a growth, the tree must not be dried out to the slightest degree. In all cases it is well to soak the whole tree in water over night.

In an experiment on various methods of planting trees at the Woburn Experiment Station, the best results, as judged by ultimate tree growth and crops harvested over a period of ten years, was obtained on nursery trees that had from ½ to ⅔ of tree roots cut off. If the trees are freshly dug and immediately planted no pruning is needed. The principle feature in planting is to ram the soil as tightly about the tree as possible. Water should be liberally poured in the hole, and the dirt thrown over the roots should be rammed down until the whole mass has the consistency of putty. The effect of such ramming is to bring the soil particles into intimate contact with the roots. In the first ten years of the Woburn experiments the rammed trees showed an excess in amount of crop of 13 percent over trees planted in the usual manner, and wood growth was also increased by ramming. The results of this experiment are given in the Woburn Experimental Fruit Farm Reports 6 - 9 for 1908.

As a rule apple trees are planted too closely together. Such varieties as Baldwin, Greening, Spy, and Mc Intosh should be planted as standard trees, at least, fifty feet apart. Whether the trees be trained to the Modified Leader type or the Leader type, this distance will be none too great. In fact a distance of 60 feet might be better. In the Udell orchard in Western New York, which is now sixty years old, Baldwin trees are about sixty feet across and less than thirty feet high. These trees were spaced 60 feet apart. In other words, where trees are crowded the growth is certain to be upright. One of the fundamental principles of this

system of training is to spread the tree for fruiting surface, rather than to grow it in height with the same object in mind. Planting the trees at good distances apart will encourage growth in width. To take up the surplus room fillers can be used to good advantage provided they be removed when they crowd the permanent trees.

Formative Age.

This is the critical period in the life of the tree because mistakes made at the start are difficult if not impossible to rectify. Certain current practices that are advised in many bulletins and books on pruning or fruit culture must be considered at this time.

Fallacy of Cutting Back Scaffold Limbs at Planting.

Probably the majority of Pomologists advise cutting back the primary scaffold branches on the young two year old tree at planting. This pruning is also practiced by fruit growers all over the country. As a rule the advice is given to choose from three to five limbs, which are to form the framework of the tree, the remaining limbs are cut away. The limbs that have been chosen are cut back to varying lengths, usually leaving the branch from three or four inches to six of eight inches long. Photograph No. 33 illustrates a tree pruned in the usual manner. The reasons given in pomological publications for this heavy cutting back at planting are, first that when a tree is dug the larger part of its feeding root system is destroyed and it is necessary to restore the balance between roots and top by cutting back the branches, otherwise the top will suffer from lack of moisture during the summer and the tree may die. Secondly that by so cutting back, the primary scaffold limbs are made to grow stocky.

For New England conditions this cutting back is not only unnecessary, but even harmful. It is not necessary because a nursery tree carries a larger number of scaffold branches than should be saved for the head. Usually there are from eight to twelve limbs on such a tree. By cutting out half of these branches the balance between root and top is restored. Also drastic cutting back of the limbs delays fruiting, since a year is required to renew the branch cut away.

A tree cut back tends to produce upright growing scaffold branches as illustrated in photograph No. page . In this way the top is crowded, with the sub-scaffold limbs and laterals forced into a small space

and thus much pruning is necessary to keep the top open, due to the poor distribution of fruiting wood. When this tree bears the difficulty will not be corrected, for the amount of bending outward of these limbs will be limited. Sedrick (14) writes as follows on this subject: "Both theory and experience lead to the belief that fruit growers usually make a mistake in the manner of pruning newly set trees. The common way is to cut back all of the branches. This in many cases is wrong. The top buds on a branch develop soonest and produce the largest leaves. Now a newly set tree will grow best if it can develop a large leaf surface before dry hot weather sets in, and this it will do if some branches are left intact. Therefore, instead of shortening in all branches, cut away some of the branches entirely. The tree so pruned will start growth and acquire vigor more quickly, and a better top can be formed.

Two ideas in regard to stockiness are held by Fruit Growers. With some it is considered that cutting back the branch makes it grow thicker. This is absolutely a fallacy, which has been ascertained at the Woburn Experiment Station. The most general idea of stockiness is that the secondary scaffold limbs are brought closer together at a point near the trunk, which results in a stronger framework. Cutting back to produce a stocky limb in the sense that the limb must be carried near the trunk, is not necessary. By proper training the first secondary scaffold limb can be obtained near the trunk, while the next one should be on the opposite side of the primary scaffold limb and about a foot beyond the first secondary limb. The scaffold branches do not need exceptional strength until fruit bearing starts. When fruit bearing begins the tree produces a few fruits. These bend the limbs outward, causing the branches to grow in thickness, but checking growth in length. More laterals are also started into growth along the branches. With some varieties thinning may be necessary to prevent extreme bending or destroying of the branches, but in the East breaking is very unlikely. In the West, however, due to intense light and longer growing seasons the trees produce long whip like branches that need shortening in or else they will break under a load of fruit.

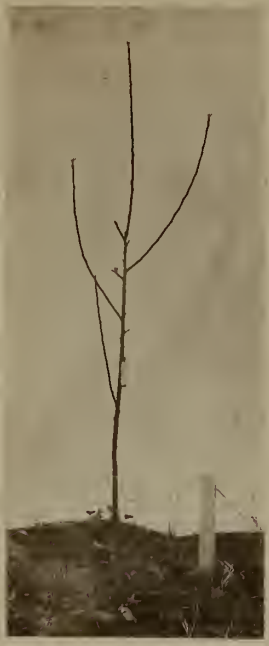
In the spring of 1915, twelve two year old trees were planted <u>without any thinning or cutting back of the branches</u>. These trees had been treated very harshly prior to planting, having been discarded and left for several days without any protection, so that the roots were dry

and the back of the limbs badly shriveled. For a couple of days they were soaked in water, which restored their plump appearance. The trees were planted in a fine sandy soil, by inexperienced men without supervision. In planting the roots were not trimmed and the soil was only lightly tread over them. The treatment given these trees was as unorthodox and severe as possible. The rainfall during May and June was light, but heavy in July and August. In the fall they werefound to have made a heavy growth of new wood and a large increase in diameter of trunk.

In photograph No.3 the thrifty condition of one of these trees is shown at the start of the second year. A number of one year old whips that were in this same lot and planted at the same time, but were cut back and the buds thinned out made an exceedingly poor growth. The growth of these trees is recorded in the chapter on Experiments on Head Formation, Experiment I, Lot B. Photograph No. shows a tree treated in this manner, which is comparable to the heading back of the branches at planting.

Heavy Pruning of the Young Tree Delays Fruit Bearing.

Many Eastern Pomologists and Fruit Growers, make the mistake of heavy cutting back of the leaders and thinning out of branches on the young trees. Although the trend of practice is in the opposite direction, there are still a number who advocate such pruning, as is evident by reading current literature on fruit growing. The trouble lies in the minds of these writers and practical growers, in that they do not understand the distinction between training and pruning and the object of each. The mistake is made of regarding the tree as a fruit bearer prior to its normal fruiting age. With the three, four, or five year old tree before them they do not have the faculty of visualizing the bearing tree at ten, twenty, or even fifty years of age. Instead of having a system of training in mind, to produce a strong tree, that is to bear superior quality apples the operation too often consistsin cutting back to make stocky limbs and to produce a large number of branches to carry the crop. Much of the wood found in the center of a tree five years or younger will never bear fruit. Such wood should consist of the primary and secondary scaffold limbs and the lower parts of some of the laterals on the secondary scaffold limbs. Little or no fruit will or can be carried



No. 18

Tree No. 1 Tree No. 2

Tree No. 1 was not disbudded. The leader and scaffold limbs grew from axillary buds on the whip. The angles are not as wide as desired.

Tree No. 2 was disbudded . The resulting growth was poor.

on this wood, so that in the center of a tree there is a solid space of about 3 ft. in diameter, in which the quantity of fruit ever carried will be negligible. Thus it is folly to attempt to prune for fruit before the tree has completed its framework.

Such pruning also actually retards fruiting. The results of experiments and observations prove this statement. Pickering (2) reports that, "When similiar branches on the same tree were pruned to different extents, it was found that the less the pruning, the greater the number, length and weight of new shoots formed and the increase in girth of the original branch."

"Similiar results were obtained in 1906 with trees of 53 and 30 varieties of the crab and paradise stocks respectively. The trees were not allowed to over bear and it is claimed that the size of fruit obtained from trees pruned to different extents was approximately the same, hence the values of the crops were proportional to the weight. Confirmatory evidence of the antagonism of pruning to fruiting was obtained by counting the fruit on similiar branches of the same tree, which were cut back to different extents."

Fraser (30) a practical fruit grower in a paper read before the Massachusetts Fruit Growers' Association in 1913 said, "My contention is that if you will leave the limbs alone and not cut them back, they will fill up with fruit spurs and come into bearing quicker. We have Baldwins five years planted bearing 1½ bushels. There is an orchard nearby which has been handled in this way, an orchard of Hubbardston's, which at four years picked half a barrel. Some of the Baldwins did the same at five and every tree in the orchard was bearing. Until a tree was in bearing I would not prune it any more than to probably take out a limb that was interfering. The early bearing induces a normal spread of the branches." We have trees five years planted, Greenings, which are bearing and have a ten foot spread. Every tree of one block were bearing at four years, one of them had 179 fruits and another 182.

Hedrick (14) writes, "For several years after planting, the peach alone excepted, fruit trees need to be pruned only to train the tree. Just how much to prune a young tree depends upon the fruit, the variety, the

soil, and the climate. Fruit growers prune trees far too much, thereby increasing the growth of wood and of leaf surface and delaying the fruiting of the plant. If trees were originally well selected all that is needed is to remove an occasional branch which starts out in the wrong place the sooner done the better and take out dead injured or crossed limbs."

Buchanan (31) in the Rural New Yorker says, "King is one of the varieties which suffered most from the old system of pruning. "Prune to stiffen up the branches," made the King grow much wood. Thin out your top, gave the owner the pleasure of cutting it out. It usually took 12 to 15 years before Kings bore much fruit."

Recent results secured by Alderman (32) in a young orchard are interesting in this regard. Two crops were secured.

	Apples per tree	Apples per tree
Heavy dormant pruning	348.6	12.45
Moderate " "	414.2	19.8
Light " "	471.7	33.32

He further says, "In another six year old orchard the only fruits produced were upon the light pruned block, and in a five year old orchard the light pruned block averaged 85 percent buds this winter while the moderately pruned block averaged 82 percent and the heavily pruned block 50 percent."

The only pruning a tree requires from the first year until fruit bearing begins is as follows:

(1) Pinch back during the growing season any branch that is markedly out-growing its fellows.

(2) Remove interfering or crowding twigs.

(3) When a branch is drooping badly from excessive weight of leaves remove some of the leaves.

(4) In certain varieties as Duchess and Wagner it is advisable to remove terminal fruit buds on the leaders. If this is not done a bad crotch will be produced.

(5) Shortening of leaders when the tree is four or five years old, in the case of certain varieties that do not branch freely may be advisable. King is an ex-

ample of such a variety. By carrying out these principles of pruning for young trees, such tardy bearing varieties as Baldwin and Spy can be made to produce fruit in from two to eight years earlier than under the heavy pruning method.

Fruiting Age.

The Influence of the Time and Amount of Pruning.

In training the apple tree it is important to clearly understand the effect on fruit bearing, of the time and amount of pruning. In New England, which has a cool damp climate, the trees tend to produce much wood and are relatively late in coming into bearing, while in the West the opposite is the rule and the trees are very precocious. For this reason in New England, when the amount of pruning is reduced to the minimum, the trees produce fruit sooner and in greater abundance. Exceptions may occur for certain varieties, which need special pruning to correct defects in growth, and in the case of old trees when rejuvination is necessary. Fickering (2) found in the experiments on pruning, noted previously, that the unpruned trees yielded nearly three times as much as the moderately pruned trees, while the hard pruned trees had practically no crop at all.

The reason for the earlier bearing of the non-pruned trees is easily comprehended, if certain principles of plant growth are understood. If dormant pruning is resorted to each year, the tree is thrown out of balance by the removal of a part of the top and as there is an excess of stored food present, this causes a vigorous growth of a number of buds that otherwise might have developed into fruit buds. On an unpruned year old whip, only two or three buds, usually near the top, will develop into twigs the second year while part of the remainder will develop into spurs and the rest may remain quiescent. The following year a number of these spurs bear fruit. Now is half of the whip had been cut away the first year, a portion of the buds that would have developed into spurs the next year would have been removed. In addition a number of buds on the portion left, instead of developing into spurs, grew into laterals. Thus instead of the whip bearing fruit buds at the end of the second year, it would contain but few if any, the buds having developed into twigs. If this process is repeated each year, it is easily seen that the tree is stimulated to the production of wood and not fruit. Fruit spurs can only be produced

by the growth of laterals that are located on wood three or four yeare old and that are out of the area stimulated by pruning.

Annual dormant pruning is often considered to develop a larger tree. Pickering's (2) results amply demonstrate the fallacy of this idea since he found that trees not pruned at all were 20% heavier than trees moderately pruned and 36% heavier than the hard pruned trees, also since the difference in weight between the unpruned and moderately pruned trees is greatly in access of the wood removed by pruning, it is concluded that pruning did not increase the actual size of the tree, but even results in less new wood beingformed. When similiar branches on the same tree were pruned to different extents, it was found that the less the pruning the greater the number, length and weight of new shoots formed and the increase girth of the original branch. This last statement is contrary to the belief that cutting back a branch makes it stockier. The writer considers that these results can be applied, with some reservation, to pruning operations in New England, since the climate of England is somewhat simiiiar to our own.

Alderman (32) records results as follows:

Influence of Pruning upon Total Yearly Growth.

	Heavy Pruning.		Light Pruning.	
	Length yearly Growth.	Diam. of trunk.	Length yearly Growth	Diam. of trunk.
Beginning of Ex.	4.41'	.33"	5.58'	.28"
1912	16.25	.73	15.51	.68
1913	41.53	1.15	34.33	1.16
1914	84.08	1.57	99.39	1.86
1915	161.74	2.17	224.89	2.91

Neither in total length of growth nor in increase of trunk diameter have the bearing of the heavily pruned trees made as satisfactory a gain as the lightly pruned ones, except at the very beginning. The only possible deduction from these figures is that continued heavy pruning acts as an inhibitor of growth rather than a stimulant. It is insignificant to note in this

connection that in all the orchards the lightly pruned trees are noticeably larger in size than the heavily pruned ones."

Summer Pruning.

Summer Pruning is practiced but little if any in the East. The strongest advocates of this kind of pruning mostly Western Pomologists and Fruit Growers operating in arid and semi arid regions, such as the Rocky Mountain and Pacific Coast states and Australia.

by summer pruning is meant the cutting back of the growing twigs at a specific time, which occurs in the growing season during a few weeks prior to the formation of the winter terminal buds. The object of such pruning is to check growth and cause buds that would normally develop leaf buds to progress on in growth to fruit buds. Lewis (17) has devised a method for training fruit trees, by summer pruning that is claimed to complete the framework of the tree sooner than by dormant pruning.

One of the great difficulties in summer pruning for fruit is to determine the proper season for doing the work. If the pruning is done too early a number of auxiliary buds are awakened into a sappy growth and are often winter killed. If the pruning is done too late, the results are negative in so far as the development of fruit buds is concerned. Recently the weight of opinion based on experimental evidence, has been against summer pruning.

Batchelor and Goodspeed (33) reported in 1915 the following results from summer pruning in a bearing orchard in Utah. Unpruned Gano trees produced, on an average, 115 more boxes of fruit per acre than did the summer pruned trees. Jonathan averaged 64¼ boxes more per acre for winter pruned trees over winter and summer pruned trees.

Alderman (32) states as a result of his experiments that, "In all cases the blocks that had received summer pruning bore a paler or yellower foliage than those pruned in the dormant season." Summer pruning also caused a great decrease in the size of leaf, number of leaves per tree and in the total leaf area per tree. He also makes a significant statement that, "In the young orchards we have attempted to correlate summer pruning

with early bearing, but correlation is negative. Merely correlative dormant pruning far exceeded all forms of summer pruning in bringing about early bearing and in some cases the moderate and heavy dormant pruned blocks produced more bountifully than did the summer pruned trees."

It is evident that summer pruning as a means of causing early bearing or to form the framework of a tree, is not sound practice for the Massachusetts grower to attempt.

Summer pruning must not be confused with summer pinching of wayward shoots. This is a ligitimate proceedure and should be practiced in all Eastern orchards. Whenever a shoot is growing out of position or over growing its neighbors, the terminal bud may be pinched off, or the shoot may be cut back.

Heading Back the Bearing Tree.

Heavy heading back the bearing tree during the dormant season, with the exception of a very few varieties to be mentioned, is as a rule bad practice. By, heading back, is meant the removal of part or all of the current year's growth of twigs, or even cutting back into the two year old wood. The reasons advanced for such pruning are, first to keep the tree low in stature, second, to fill up the top with twigs to carry fruit, thirdly, to keep the fruiting spurs at the base and center of the twigs and not at the top, and finally as practiced in the West, to produce a dense shade to protect the limbs from sun scald.

Heading back has its place in the training system, but as often carried out there are a number of objections to its indiscriminate use. Hedrick (14) says, "Heading-in makes the top of a tree thicker and broader. There are but few orchards or even trees that do not need more or less heading-in at some time in their history. But in our climate this form of pruning is practiced only with peaches and some plums and is but little needed with other fruits unless it is summer heading-in described before. In the winter the cutting back of exceedingly long branches or the thickening of the top of occasional trees or varieties is the exception rather than the rule".

The heading back of the current year wood in the top does not prevent the tree from increasing in height

each year. For example if the length of the current year's wood is two to two and a half feet long and if this is cut back to six inches or a foot, the tree has increased in height to that extent. Also some of the buds on these twigs will be stimulated to a growth of two to two and a half feet, with the result that the process of cutting, followed by growth is repeated each year. Thus the tree increases in height from year to year. There is a way, however, to keep the tree within bounds by, heading back, which will be discussed in another paragraph.

Another objection to, heading back, is that such dormant pruning results in the production of a bushy top. Each leader that is cut back, produces two or more laterals from the auxiliary buds. In this way, the top of the tree becomes filled with a great number of growing twigs, packed closely together. The following spring, the same growth takes place if, heading back, is performed again. In the Photograph of the young tree the leader has been cut back severely. Note that ten long laterals located within a space of one foot, grew in all directions from the leader. It can easily be seen that to cut back the one year old twigs in the top of a bearing tree would be to produce a great number of new twigs, all of which would grow on the extreme outside of the head.

Heading back young trees that are starting to bear and continuing the practice results in diminishing the quantity of fruit produced.

Batchelor and Good speed (31) report results on Gano and Jonathan trees, one lot of which were pruned by cutting back the terminal growths to make the head spread, while the other lot were allowed to assume a more natural upright growth, with out heading back. The trees were five years old when the experiments were started and bore four crops while the investigations were in progress. The ratio of the total pound of marketable fruit for the two varieties during four years is as follows:

	Allowed to take Natural shape	Headed back to spread
Jonathan	100	86
Gano	100	91

Gardner (34) who has written a very enlightening article on heading back and thinning out says, "Heading back seems to show a tendency to divert food material into new shoots rather than the old spurs. These new

No. 19

Heading Back

Young tree with the scaffold branch headed back.

shoots develop mainly in the outer and upper parts of the tree, leaving the spurs in the lower and inner portions in a weakened condition. The result is that they will probably bear less regularly and die earlier than spurs which have an abundant food supply. Furthermore very heavy heading back will even force into shoot growth some of the already formed spurs. Thinning out, on the other hand, will not only divert an extra amount of food material into the older fruit spurs on account of its reduction of shoot growth, but it also lets light into the center of the trees, so that the leaves of each spur are better able to manufacture the food materials needed to keep these vigorous and thrifty. This should enable them to live longer and bear more regularly."

Heading back when properly done can be used to prevent certain varieties from fruiting near the ends of the twigs. But when carried out by cutting back the majority of year old twigs in a tree, the result is the production of wood and not fruit buds.

Heading back to shade the limbs is not needed in the East, but should be practiced to a limited extent in the case of the King, to prevent the fruit from sun burning.

In training a tree, there is often need of heading back a limb, or even the whole top. It may be used to curb a rank growing limb, in which case the limb should be cut back, and later in the season the excess twigs, that develop should be thinned out. In fact, it may be advisable, in many cases, to do the cutting during the summer, to prevent the excess of growth, which follows dormant pruning.

To check the tree in its upward growth, other means than heading back may be employed. In regard to curbing growth in heights, Hedrick (14) writes, "Since heading-in is usually practiced to reduce extensive growth, it is always best to consider if there is not some way of preventing too much growth, as through withholding fertilizers, not pruning in winter or by use of cover crops. In other words, it is better not to force trees than to produce too much wood and then cut it off."

The secret of successful heading back to reduce the height of the tree, rests largely in cutting back to a side branch, located on wood of several years growth. Such pruning will result in the growth upward of the branch and the development of its laterals. It

will not, however, result in an outburst of many twigs, such as results in cutting back on year old wood. Wickson (28) clearly outlines this method as follows: "Cutting back or 'shortening in' should be done in a way which will reduce the burst of new shoots near by always cutting the branch at a strong lateral because the sap flow into this lateral prevents undue pressure and forcing of latent buds in the vicinity of the cut. For this reason the cutting back of all branches to a certain definite height is wrong. Trees shorn across at a certain line become thick as a brush with top shoots which require extensive thinning or the bearing wood will soon be all at that level through failure of the densely shaded bearing wood below. Cut to the nearest lateral below the line you wish to approximate and shorten the lateral, if desirable, and the result will be fewer and stronger shoots than from a stub cut." See Photograph #20

During the first year or at the start of the second year the new growth in the top should be thinned out, by completely cutting out crowding twigs.

To sum up, heading back should only be resorted to in case of absolute necessity.

Thinning the Top.

In the system of pruning to be outlined, one of its chief features is the construction of the head, so that sunlight can penetrate easily to all parts of the tree. As the tree increases in age, pruning will have to be done, with three objects in view, first to keep the head open and vigorous or thinning, second, to prevent the tree from growing too high and thirdly, spur rejuvenation, which will only occur when the tree has borne many crops.

In reviewing the literature of pruning, it is worthy to note, that even the earliest writers recognized the need of admitting light into all parts of the tree. Wickson (28) in writing of the necessity of thinning says, "In the treatment of bearing trees the main effort should generally be towards thinning or reducing the number of bearing shoots."----"An unthinned tree becomes a thicket of small, weak and dying laterals and spurs."

"The only way to keep the interior of the tree full enough of strong bearing wood is to resolutely and regularly thin out surplus shoots, as the tree advances

No. 20

A Headed Back Tree

The one year old wood was clipped back about half its length. The tree contains too much wood due to the previous year's heading back. Instead of heading back the tree should have been thinned out.

in age and size. This work is as important with trees which are not regularly cut back, as with those which are thus treated. It is one of the most vital as well as the most generally neglected tems in orchard practice.

Van Alstyne (38) a prominent fruit grower of the Hudson Valley speaks of the value of thinning the top as follows: "I remember, some years ago, we had very cold storms at the blossoming of the Baldwin, which, with us, as with most of you, is our great market apple. The Baldwin crop looked as if it was seriously damaged, and so it was; yet I found on my own trees, (I had been pruning to get fruit buds in the interior), I had a very respectable crop after all, the apples came from the interior of the trees where they were protected--the buds had gone on and developed, where, at the extremities, they were destroyed.

The amount of thinning out will vary according to the habit of growth, age and vigor of the variety.

Those varieties that tend to produce an abundance of long, many branched, leafy laterals and twigs, will require more thinning than those that produce many short laterals and spurs. For example, McIntosh, Baldwin, Ben Davis, Hubbardston, Jonathan, Spy, Rhode Island Greening will require annual thinning, while King, Spitzenberg, Roxbury Russet, Hutton and Wagner will require little thinning. In fact, some of these varieties will be benefited by an occasional light heading back.

Thinning out should be done from the outside, working towards the center of the tree. Remove weak and crossing branches or twigs growing closely parallel to each other. Thin out along the branches to the center of the tree. The work should be done annually and the necessity of removing a large branch to thin the top should never occur.

As a rule, do the thinning in such a way that the laterals and twigs will not have a crooked growth. This can be done by removing the growth entirely, back to the lateral. Finally keep in mind the fact that widely spacing the scaffold limbs will aid greatly in reducing the amount of thinning. Avoid stimulating the trees to excessive growth by fertilizers or cultivations. Thin out each year, so that the amount of pruning will not have to be excessive and thus avoid exuberant growth due to heavy dormant pruning.

Thinning Fruit.

In the production of superior fruit, thinning is an important factor. This practice also has a place in the formation of the head of a tree, no matter what system may be followed.

With the method of training advocated in this paper, thinning of the fruit when the young tree starts to bear is strongly advised. Many varieties produce lateral fruit buds near the ends of the current year's wood and also the terminal bud may be a fruit bud. This system permits of a maximum bending of branches, without breaking of the head or dense shading of other branches, but until the limbs become stocky, it is not advisable to permit such extreme bending. The objections to allowing such bending, are that the lower branches will be inclined to the ground, so that the branches and fruit will rest on the soil and also that the laterals are twisted out of shape.

To be successful orchard practice thinning must be profitable. The following figures are a few that have been selected from a number of such statistics, to prove that thinning is highly profitable and is in fact, indespensable in the production of first quality fruit.

Close (13) reports the results obtained by thinning as showing from 1½ to 3 times the amount of first grade fruit picked from thinned trees over the non-thinned trees.

Bennett (35) found that the increased value of fruit due to thinning varied from 77½¢ to $1.83 per tree. The variety was Baldwin.

Fisher (11) writes that as a result of experiments it is concluded that thinning pays on heavily loaded trees.

Batchelor (33) results on eight year old Ben Davis trees thinned four inches apart gave a net increase of $1.16 per tree. Eight year old Jonathan gave an increase of 30¢ per tree in 1911 and 71¢ per tree in 1912. The cost of thinning is off set by less cost in sorting the fruit.

Whipple (37) found that thinned Winesap trees show a gain over non-thinned trees of $1.85 per tree.

Beach (21) in a thinning experiment reports: In seasons of heavy crops thinning was found to heighten the color and increase the size of fruit of Baldwins, Hubbardstons, and Rhode Island Greenings. On a small crop the results were negative. The cost of thinning a well loaded tree should not exceed 50¢. Thinned trees bear a larger percentage of first grade fruit than unthinned trees and the fruit is much better adapted for marketing fancy grades.

Blair (39) obtained the following results in an extensive thinning experiment in Nova Scotia.

The work was done two weeks after the June drop but should have started ten days earlier for the best results. The variety was Gravenstein. From the thinned trees all spotted and ill shaped fruits were removed and only one apple was left to a fruit cluster. The apples were left four to six inches apart.

Increase in Size.

Apples to the barrel from thinned tree.	517
" " " " " unthinned "	593
Per cent increase in size from thinning.	12.81%

Grade of Fruit.

	Thinned tree	Unthinned tree	Increase
No. 1	70.00	42.00	28%
" 2	23.80	38.65	
" 3	5.60	16.13	10.55%
Culls	.60	3.22	

The cost of both thinning and grading the thinned fruit was 11 1/3 ¢ per barrel. The cost of grading the unthinned fruit was 10¢ making the cost of thinning 1 1/3¢ per barrel.

Value of thinned fruit	$11.94	
" " unthinned "	10.10	
Gross returns per tree for thinning	1.76	
Net " " " " "	1.74	
At rate of 40 trees per acre	69.60	profit by thinning.

Another experiment in thinning on Ben Davis, Stark and Rhode Island Greening trees comprising five acres in all tested different amounts of thinning as fruit 8, 6, and 4 inches apart, thinning one fruit to a cluster and general tainning. In all cases thinning increased the percentage of Nos. 1 and 2 fruit and greatly decreased the percentage of No. 3 and culls.

EXPERIMENTS OF HEAD FORMATION.

In order to clear up certain problems bearing on the proper heading of trees, the following experiments were conducted during the growing season of 1915. These problems were corrected with the proper spacing of scaffold branches; the method of forming heads of the Modified Leader tree and the Leader tree; the number of seasons it takes to grow the primary scaffold branches for the Modified Leader tree and certin experiments in the forcing of buds at points where scaffold limbs were desired.

Discussion of Problems.

How many growing seasons are necessary to develop a Modified Leader tree having four or five scaffold limbs?

Lewis (17) page 23, states in speaking of the Modified Leader tree, "but beginning from the second to the fifth year, the leader is suppressed." We are unable to find in this bulletin any other reference to the length of time required to form a head. Evidently Lewis infers that the head may be formed in from one to four years.

Since the scaffold limbs are to be separated 8 inches or more, the distance between the lowest branch and the highest branch will be 24 inches. If the first branch is 20 inches above the ground, we must have a trunk 3 feet 8 inches long to start with, if we wish to develop four scaffold limbs the first year.

Nursery men grade apple trees as follows:

Largest size	2 yr.	5 - 7 ft.	Branched trees
Medium "	2 yr.	4½ - 6 ft.	" "
Smaller "	2 yr.	4 - 5 ft.	" "
Largest "	1 yr.	3 ft. and up	Whips unbranched

It is easily seen that only the largest and medium sized two year old trees and whips over 56 inches would be tall enough to develop the Modified Leader head, with four branches separated 8 inches or more. With five

branches the head cannot be obtained on any of the above trees. The question how long will it take to obtain the additional branches necessary to make the full quota of scaffold limbs then arises.

The importance of having the scaffold limbs well separated on the trunk and leaving the trunk at a wide angle presented certain problems that were investigated. These two factors in addition to obtaining a wide spread to the scaffold limbs were fundamental parts of the experiments. In all the training work on the trees used in the experiments these factors were carefully studied and methods and rules of training were sought that would enable the fruit growers to develop the ideal head. Parts I, II, III, IV include these factors of separation of branches, branch angles and spread of branches, in addition to the general heading problem.

The question arose, could a two year old tree with the head already formed be planted and one or more of the scaffold limbs, well separated and wide angled be retained, the surplus limbs being pruned off? The usual two year old tree has from six to ten limbs arising on the trunk in a space of about twelve inches or less. If one or more of these limbs separated 8 inches or more could be retained, a year would be saved in the growth of that number of scaffold limbs. In addition the tree would have the advantage of just that much more leaf surface. The importance of retaining the branches on the young tree, from the stand point of growth and early fruiting, has been discussed in a previous chapter. It was feared that the scaffold limbs retained would outgrow those developed from buds on the leader.

Part IV was planed to investigate this problem. Photograph No. 21 illustrates a two year old with one scaffold limb and leader retained and six branches removed as indicated. On two year old trees it often occurs that a long scaffold branch is not present at the desired point on the trunk, but instead of short slender so called Prong bud may be located at this place. Such buds being from one half to two inches long, rather slender and always at a wide angle with the trunk. The question arose, could such a bud be forced into growth and developed into a strong scaffold limb. Part V covers this point. Figure No. 6 shows a number of prong buds growing in the trunk where the scaffold limbs are needed.

Plan of Experiments.

Experiment I. Whips having a terminal bud and three, four or five buds chosen for scaffold limbs after growth had progressed about an inch in the spring. These buds were spaced 8 inches or more apart. All intervening buds removed. This is termed "Severe early disbudded." The first bud was chosen at twenty inches from the ground and all buds below it were rubbed off. See Photograph No. 22.

Experiment II. Whips were treated in the same manner as in No. I except terminal bud was removed at a height of about 56 inches from the ground.

Experiment III. Whips were left unpruned and all branches allowed to grow except those growing on the trunk at a distance of twenty inches from the ground. These were considered checks and unfortunately only a few were included in Section A. See Photograph No. 23. Another lot of trees in this experiment were left untreated. That is no buds on the whip were removed.

Experiment IV. Two year old trees were used in this experiment. A wide angled spreading scaffold limb was chosen about 20 inches from the ground. All the remaining scaffold limbs except the leader were removed. If another limb was present, with a wide angle and spaced eight or more inches above the first it was also retained. The leader was disbudded to two or three buds. On two year old nursery trees it is rarely possible to retain more than two scaffold limbs. Photograph No. 21 illustrates a tree as pruned in the spring just after the growth started.

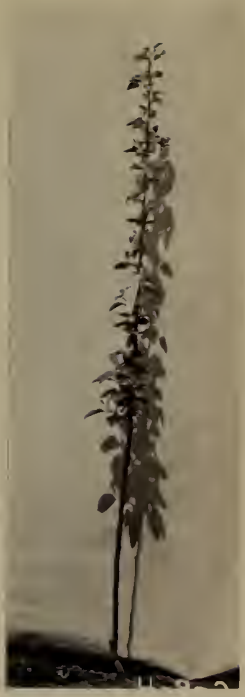
Experiment V. Trees with one or more prong buds were treated as in Experiment I, II, or IV. That is the prong buds were saved, when well spaced and intervening buds removed.

The Plantings.

Two lots of trees were used, one designated as A consisted of two year old trees and one year old whips, which were growing in the nursery. These trees were not transplanted, but were experimented on in situ. The varieties were 23 Baldwins, 46 Wealthy, 24 McIntosh and 15 Palmer Greenings. Lot B consisted of 125 trees the majority of which were whips. The varieties were 32 Red Astrachan, 15 Tolman Sweet, 17 Wagners, 13 Yellow Trans-

No. 21

A two year old tree pruned with a leader and one scaffold branch. At 1, 2, 3, 4, and 5 were branches that were pruned off, since they were too close together. One branch growing upright was saved for the leader and buds #2, #3 and #4 were saved to develop scaffold branches. The intervening buds were rubbed off. This practice of rubbing the buds off just after they start in the spring is termed in this thesis, "Severe early disbudding."



No. 22 No. 23

Number 22 illustrates the treatment given the whip in Experiment I.

Number 23 was taken of a whip treated as in Experiment I.I.

parent, 23 Esopus. These trees were treated very harshly prior to planting. Not being needed for the Root and Cion Experiment, an Experiment Station project, they had been discarded. After several days they were restored, but by this time the roots were dry and the stems shriveled. Before planting they were soaked in running water for several days until all effects of drying had disappeared and the roots and stems presented a bright plump appearance. The writer considers this revival of these nursery trees an important procedure to be followed before planting any trees no matter how fresh they may seem. If these trees had been planted immediately we feel sure that few if any would have grown. The trees were planted in a very sandy soil, by workmen who did not carefully pack the ground about the roots. The growth of the trees was not at all satisfactory and was largely due to the poor planting. As has been discussed in a previous chapter, the important point in planting trees is to pack the soil as firmly as possible about the roots. Both A and B were cultivated every two weeks until the middle of July, when a cover crop of Buckwheat was sown in lot A. No cover crop was sown in lot B.

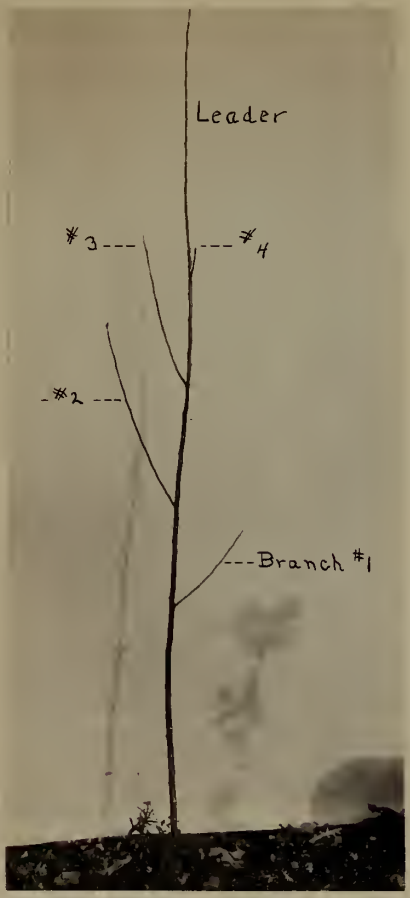
Treatment During Growing Season.

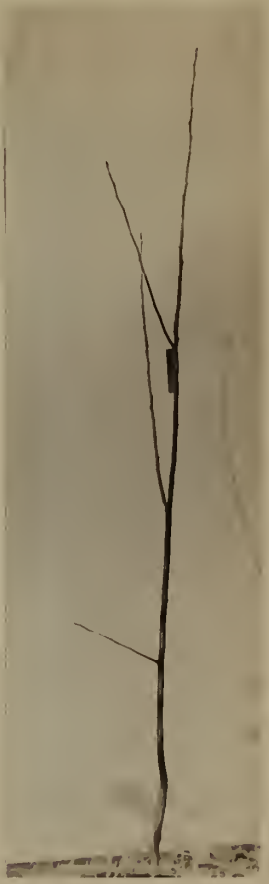
Lot A. Since these trees were established in the soil, they made a very rapid growth. In some instances the leader grew so tall and carried such a weight of leaders that the trees bent over and grew crooked. Limbs drooping or outgrowing their neighbors were pinched back, otherwise the trees were not pruned except in cases noted under results.

Lot B. Lot B required little care as the trees did not make a vigorous growth.

Explanation of Terms.

In all cases the branches are numbered from the ground up. Thus the first scaffold limb is No. 1 and the second No. 2 etc. Photograph 24 illustrates the method of numbering the scaffold branches. The branch angles were measured with a six inch protractor. The spread of the branches were defined as follows. Wide spreading= . S. were those branches where the arc made by the branch and trunk was 70° to 90°. A wide spreading branch is seen in





No. 24

No. 25

Photograph No. 24 illustrates the method of numbering the branches. See Page 67, Explanation of Terms.

Photograph No. 25, limb # 1, illustrates a wide spreading (W. S.) limb.

Photograph ~~Figure~~ No. 2 Limb No.1. Spreading= 1. A branch making an angle between 50° and 70°. See Photograph No.14 Limb No. 1. Photograph ~~Upright~~ U. A branch making an angle less than 60°. Photo Photograph ~~Figure~~ No. 18 Limb No. 2. To compare the growths made by the various treatments the trees were calipered. A tack was driven in the trunk a few inches above the ground and the thickness of the trunk at the point was measured in the spring and fall. Total growth of scaffold limbs was also measured in some cases.

Results of Experiments I and II.

Effect of Selection of Buds for Primary Scaffold Limbs by "Severe Early Disbudding".

The trees in these two lots were treated the same except Experiment II had the terminal bud removed. Removal of the terminal bud of the leader is bad practice, since the upper scaffold limb attempts to become the leader and making a narrow angle and an upright growth. This upright growth in experiment II will be considered in the paragraph on spread of branches.

The effect of selecting buds properly placed just as growth starts early in the spring that will develop into the permanent scaffold limbs and rubbing off the intervening buds did not give the desired results in all cases. The objections to "severe early disbudding," are first that the proper orientation of the limbs is not always certain and, that the branch angles and spread cannot be controlled.

Table I.

This table enumerates the average number of permanent scaffold limbs developed in one year on the tree of the different varieties in Lot A .

Exp. No.	I	II	III	IV
Baldwin	3+	3+	3+	3+
Wealthy	3+	2+	3+	3+
McIntosh	2+	2+	3+	2+

Lot B gave similiar results.

No. 26

Limb # 1 illustrates a spreading branch,
limb # 2 an upright branch.

The table shows that it is here possible to develop a head with four or five scaffold limbs, in one growing season. Although no extensive experiments were attempted, it was found that by pinching off the leader when it had reached a sufficient height, additional scaffold limbs could be forced out on the leader. In this way it may be possible to complete the Modified Leader head in one year. A few Modified Leader trees having four or five branches were secured in one growing season. These trees, however, were in Lot A.

Table II.

Spread of Scaffold Branches. Lot A.

	Baldwin			Wealthy			McIntosh		
	W.S	S	U	W.S	S	U	W.S	S	U
Limb No. 1									
Ex. No. 1:		2:		3	3:	1	1	3:	3
II:	1	1:	1		4:	2		4:	2
IV:	1	8:	3	3	7:	1	2	2:	
Limb No. II									
Ex. No. I:		2:			3:	3		5:	1
II:		3:			1:	5		4:	2
IV:		9:	3	4	3:	8		2:	2
Limb No. III:									
Ex. No. 1:		1:			4:	5	1	2:	1
II:		9:	1	2	6:	7	1	2:	1
IV:		2:	1					2:	2
Limb No. IV									
Ex. No. I:		1:				2	1	2:	1
II:								2:	2
IV:		1:	3	3		1	1	2:	1

The table arranges the branches of each tree starting with the lowest No. 1 according to their spread outward. On studying the table it is noticed that the limbs No. 1 and No. 2 are usually spreading or wide

spreading. Also that the greater number of limbs Nos. 3 and 4 are spreading or upright. Note ~~figures~~ Photographs Nos. 24 and 25. The method of rubbing superfluous buds off early in the season or "severe early disbudding" thus induces the upright growth of the upper limbs. Also in comparing Experiment I and II it is seen that Experiment II with the terminal bud removed, tends to have fewer wide spreading branches and more upright branches. This is especially noticeable in limbs Nos. 3 and 4. Note Photographs Nos. 26 and 27 Spread of branch is correlated with width of angle to the extent that a narrow angled limb is always an upright grower. On the other hand, a limb may start with a wide angle, but make an upright growth. This fact is important to keep in mind in heading trees such as Rhode Island Greening, that make a wide spreading head and have the lower fruiting laterals often dragging on the ground.

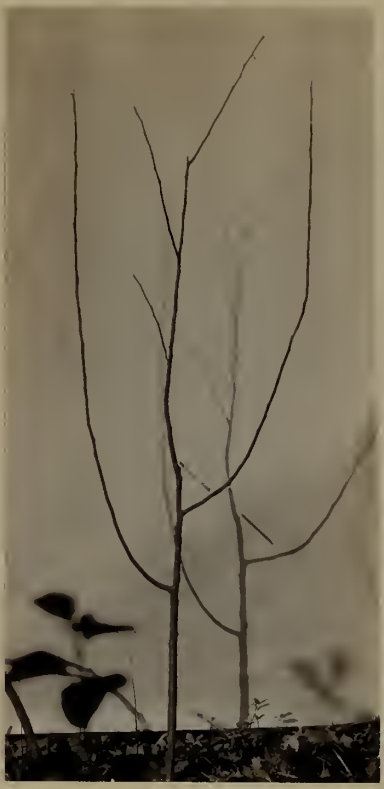
With such varieties the limbs can be started with a wide angle by not removing any buds, then when growth has progressed for a foot outward, the intervening buds between the permanent scaffold limbs can be removed, causing the branch to shoot upward. Figure No. 3 brings out this point, which is discussed in detail under Method of Heading Young Trees.

Table III.

Branch Angles. Lot A.

Average Measurement of Branch Angles in Degrees.

	Baldwin Experiment				Wealthy Experiment			
	I.	II.	III.	IV.	I.	II.	III.	IV.
Limb I.	52	53	80	66	58	47	80	65
" II.	47	46	70	50	47	39	70	48
III.	45	40	60	46	47	27	60	43
IV.			60	36	42		60	50



No. 27

Upright growing scaffold limbs caused by severe early disbudding. See page 70. Limb # 1 grew from a "Prong bud".

	McIntosh Experiment				Palmer Greening Experiment			
	I.	II.	III.	IV.	I.	II.	III.	IV.
Limb I.	48	42	80	:	48	49	80	
II.	47	40	70	:	50	44	75	
III.	38	34	70	:			70	
IV.	38	34	60	:			60	

To obtain these results the angles of each limb were measured and then the average was taken of all the limbs in the same position on the trunk.

Table IV. Lot B.

Average Measurements of Branch Angles in Degrees.

	Red Astrachan			Yellow Transparent
	Ex. I	Ex. II.	Ex. III.	Ex. I - III.
Limb I.	54°	60°	51°	60°
II.	46	51	49	64
III.		45	54	65

The measurements of the branch angles confirm the results noted in spread of branches. Experiments II in nearly all cases produced the narrowest angles, exceptions being limb No. I on Baldwins, in Lot A and Red Astrachan on Lot B. In the case of Lot A Baldwins, the data was collected on two trees only, so that the results are far from conclusive. Lot B Red Astrachan, the data is based on the measurements made on eight trees in Ex. I and is considered within the limit of experimental error. On 29 Wealthy and 16 McIntosh with the exception of three trees all the limbs were wider angled in Ex. I and IV than Ex. II.

Limbs Nos. 3, 4 and 5, when present, were so often less than 50° that the results offer more evidence that, "severe early disbudding" may produce narrow angled limbs.

The trees in Lot B in Ex. I and II made a very poor growth, in many cases the scaffold limbs did not grow longer than a few inches. Due to this non vigorous

growth there was not the necessary competition for space between the limbs, so that they tended to make upright, somewhat narrow angled limbs in all the experiments in these lots. This poor growth the writer considers to be due partly to poor planting and partly to the severe disbudding. The trees started out in the spring and completed the growth of the limbs in about four to six weeks. Then they rested for a few weeks. On the trees in Experiments I, II, and IV the next vigorous growths usually occured on the trunk between the ground and the first scaffold limb. Many branches developed at this point and grew vigorously. In no case was it possible to stop this growth by pinching off the terminal bud and forcing the growth of the scaffold limbs above. Such a growth is often seen on trees the first year planted in the orchard. In such cases, however, it is considered inadvisable to prune off these growths. Since it is not possible to start the growth above by pinching or pruning, the development of these lower twigs is a benefit to the tree in giving additional leaf surface for the manufacture and storing of food. The following spring they can be removed. The important evidence furnished by the poor growth of the tree in Lot B so far as lack of spread and development of wide angles is concerned, is that strong vigorous trees only should be planted, and that careful attention should be paid to packing the soil about the roots. With healthy, vigorous trees, carefully planted, spreading limbs can be developed by methods outlined in another chapter.

Experiment III. All the trees in this experiment were whips. When the experiments were planned these unpruned trees were included as checks for growth, comparisons with Ex. I, II and IV. It was not anticipated that the results of non pruning of the trees might present features of value for training. For this reason only a few trees of McIntosh and Wealthy in Lot A were used for this experiment. In Lot B many more trees were included.

The treatment consisted of rubbing off the buds on the trunk below 24 inches and allowing all others above this point to develop without any further pruning. The treatment given these trees is illustrated in Photograph No.29. Without exception when the trees were so treated, they made the best growth of any in these experiments in developing wide angled and wide spreading scaffold limbs. See Table No. 3 Page 70.

Photograph No.28 is of a tree which was not disbudded. The photograph was taken after the leader had been inadvertently cut back. This is a very fine type

No. 28

A tree not disbudded on the leader. Buds below twenty-four inches from the ground were rubbed off. Notice the wide angled spreading branches.

of tree to head according to the ideal type desired. To obtain a thrifty growth, with the development of wide angles and wide spread the trees must be carefully planted and the branches must compete for space. This competition for space is best afforded by this method of non disbudding, except at the point below 24 inches or so, on the trunk. Those trees that were not disbudded at any point on the trunk gave a poorer distribution of branches, although the angles and spread were wide.

Table V.

Width of Angles, Spread and Number of Limbs on Trees in Experiment III.

Wealthy	Angle of Limb No. 1	Spread of Branch	Angle of Limb No. 2	Spread of Branch	Angle of Limb No. 3	Spread of Branch
Tree No 1	80°	W. S	80°	W. S		
" " 2	Spur		90	W. S	Spur	
" " 3	90	W. S	Spur		Spur	
" " 4	80	W. S	"		60°	S.
" " 5	60	S.	"		"	
" " 6	80	W. S	"		"	
" " 7	80	W. S	"		"	
" " 8	80	W. S	"		"	
" " 9	70	W. S	80	S.	"	
" " 10	70	W. S	60	S.	70	S.
" " 11	80	W. S	Spur		Spur	
" " 12	80	W. S	60	S.	60	S.
" " 13	70	W. S	70	S.	70	S.

McIntosh	Angle of Limb No. 1	Spread of Branch	Angle of Limb No. 2	Spread of Branch	Angle of Limb No. 3	Spread of Branch
Tree No 1	90°	W. S	Spur			
" " 2	90	W. S	80	W. S		
" " 3	80	W. S	80	W. S	80	W. S
" " 4	80	W. S	80	W. S	80	W. S
" " 5	80	W. S	80	W. S		
" " 6	90	W. S	Spur			

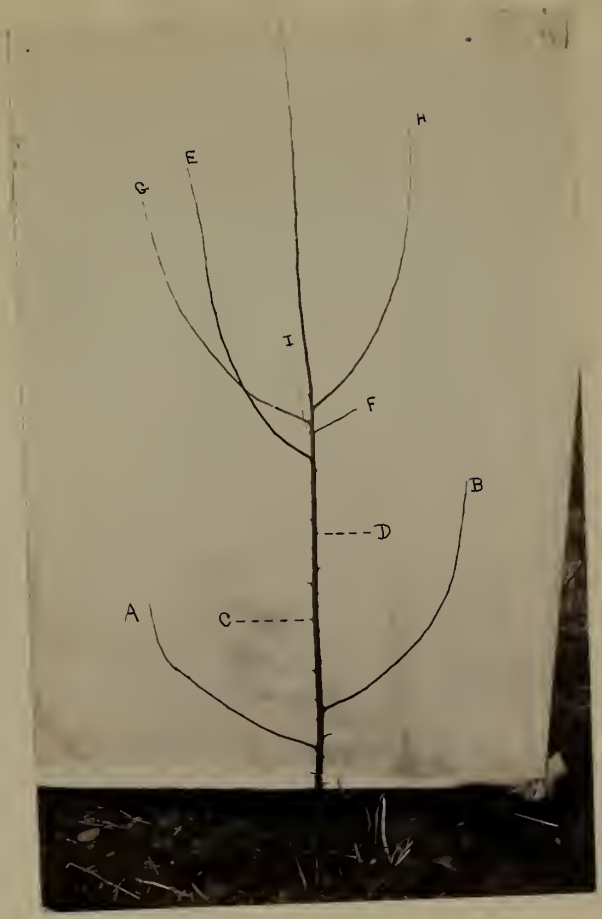
From this table it can be seen that three well separated branches can be selected at the start of the second year if the Modified Leader type is the head chosen and the head can be completed in the second growing season.

The greater number of trees in this experiment were not disbudded at any point on the trunk. Photographs Nos.27 and 35 were taken of typical trees of this type. The uneven, poorly distributed growth of these trees is noticeable. In addition fewer branches develop the first year on such trees than on those with the lower trunk disbudded.

In Lot B, the trees were not disbudded, the results while uniformly better in all cases than Ex. I and II, were not as good as desired. The angles were somewhat sharper and the spread was generally at an angle of 50° to 45°. For illustration note Photograph No. 30. Due to exposure and poor planting, these trees lacked vigor, which was responsible for their poor growth. Retaining the buds in this case caused nearly twice the increse in growth of trunk over Experiments I and II. If these trees had been disbudded below the point at which the head had been started, the results would have been much better. The disbudding would have provided surplus food for the remaining buds and a more vigorous, wider angled limb would have resulted.

Two Year Old Trees Disbudded and Pruned.

Photograph No., 21 illustrates the spring treatment of the two year old trees in this part. Branch No. 1 was grown in the nursery and was saved as the first primary scaffold limb for the tree's framework. Note the



No. 29

A tree not disbudded at any point on the trunk.

wide angle it makes with the trunk. At 1, 2, 3, 4, 5, and 6 the other branches were pruned off, saving the leader. Unfortunately the good results secured from the treatment, as practiced in Part III in obtaining wide angled, wide spreading branches was not anticipated. For this reason no trees were included in this lot, in which one or two well placed and wide angled scaffold limbs were retained and the leader not disbudded. In all cases the leader was disbudded as in Parts I and II. ~~Illustration given in Photograph No., II~~.

In the past, if the fruit grower was not satisfied with the head formed on the two year old tree in the nursery, the tree was pruned to a whip and a new head formed. The advantage to the tree is easily seen if one or more of these primary scaffold branches could be retained and not have them, "over grow", the leader or the other primary scaffold limbs developed from auxiliary buds or spurs on the leader. One year's growth would be gained for each of these limbs saved and the additional surface would serve to increase the growth of the tree.

Table VI.
Experiment IV.
Results of Treatment on Two Year old trees with One or Two Scaffold Limbs Retained.

Block A. Variety	No. of trees having one S. L. saved.	No. of trees having two S. L. saved.	No. of trees having three S. L. saved.	No. of trees where S. L. saved outgrew other limbs.
Baldwin	7	5	1	0
Wealthy	16	3	6	0
McIntosh	4	0	1	1
Block B. Wagner	5	0	0	0

Drooping of the limbs was due to the weight of the leaves dragging the limb towards the ground. Wealthy produces very large leaves, and slender branches which accounts for the large number of scaffold limbs that drooped. It is stated in a previous paragraph that severe disbudding in the early spring as practiced in Parts I, II, IV, and V

is not the proper practice to follow in forming the heads on trees. In Part IV such practice caused a very vigorous growth, which led to drooping of the limbs and also bending over of the tree, due to the weight of leaves on the leader. In the method to be outlined for heading trees, drooping of the scaffold limbs in two year old trees, where one or two scaffold limbs are saved, will be obviated. If for any unforseen reason such drooping should take place, the removal of half of the leaves, starting at a point just back of the terminal bud, will rectify the trouble. In no case should the terminal bud be pinched off to correct drooping.

"Over growing," of the other scaffold limbs, by the limbs retained on the two year old trunk, occured in a few instances. This "over growing," would not be harmful since it would be checked in a year or so by the greater vigor of the upper limbs. The chief objection to "over growing," is that the limbs assume an upright growth and crowd the head, which feature is to be avoided. "Over growing," would rarely if ever occur, in trees treated as in Part III.

The result in this experiment comfirms the practice, as expedient, of retaining one or more primary scaffold limbs on the two year old trunk and pruning back the rest. The remaining scaffold limbs to be grown the same or the next year on the leader. Limb No. 1 in Photograph No. 26 was a scaffold limb that was retained. Notice that during the first year of its growth, a secondary scaffold limb grew. The upright growth of these limbs was due to early disbudding.

Development of Prong Buds. Part V.

Will Prong Buds develop into Good Scaffold Limbs? In this Experiment were seven Baldwin trees, eleven Wealthy trees and two Palmer Greening trees that carried buds on spurs from $\frac{1}{4}$ to 2 inches long, which were termed "Prong Buds." In every case these Prong Buds developed strong scaffold limbs when the two year old trees were subjected to the disbudding process. No trees were experimented on in which all buds on the leader were allowed to grow and one or more Prong buds forced into growth. This point will be investigated in the continuation of these experiments. However, it seems safe to state that if the two year old tree has a number of branches pruned off and a Prong Bud retained with one of the long scaffold limbs and no disbudding of the leader, the Prong Bud will develop

a satisfactory primary scaffold limb. In Photograph No.27, limb No. 2 grew from a Prong Bud.

Table VII.
Growth Measurement.
Average Increase in Growth of Trunk for Season of 1915.

GROUP A.

	Exp. No.	Wealthy No. of trees	Wealthy Av. inc. in Growth	McIntosh No. of trees	McIntosh Av. inc. in Growth	Red Astrachan No. of trees	Red Astrachan Av. inc. in Growth
Disbudded	I	6	5.8	6	7.2	8	3.6
"	II	8	6.0	6	6.8	4	1.2
Not "	III	4	6.0	6	6.7	8	5.1
Two year old disbudded	IV	15	5.5	4	7.5		

GROUP B.

	Exp. No.	Tolman No. of trees	Tolman Av. inc. in Growth	Wagner No. of trees	Wagner Av. inc. in Growth	Yellow Transparent No. of trees	Yellow Transparent Av. inc. in Growth
Disbudded	I						
"	II	9	2.3				
Not "	III	5	4.8	8	4.0	13	5.0
Two year old disbudded	IV	5	2.4				

The results of the measurements in Group A are so nearly alike that they lie within the limits of experimental errors. These trees were not transplanted, but experimented on where they stood in the nursery. For this reason the trees were not forced to establish their roots in the soil, and growth started unchecked in the

spring. Disbudding, evidently did not the first year adversely effect the growth of trunk of these whips and two year old trees. On the disbudded trees evidently the resultant heavy growth of leaves equalled the leaf surface of the untreated trees. Conclusive results were obtained in the case of trees in Group B. that were planted the same spring they were disbudded. By comparing the trees in Experiments I, II, and IV it is seen that the trees in Experiment III made twice the growth of the former trees. It is unfortunate that Wagner and Yellow Transparent trees were not included in Experiments I, II, and IV in order to present a more complete result. However, these varieties made practically the same gain in growth of trunk as Tolman and there is no evidence, judging from the growth of other varieties in Experiments I, II and IV, that they would have given different results.

The results of these experiments emphasize the fact that "severe early disbudding", which is a form of pruning, should not be practiced on newly planted trees. Such treatment closely parallels the severe cutting back of newly planted two year old trees.

Disbudding and Pruning at Planting.

There is great need of investigational work on pruning and its effect on growth. The evidence presented so far as a result of such research is quite contradictory. Considering pruning in general regardless of the amount to time, the concensus of opinion is that the trees should be pruned as little as possible. On the other hand, numerous investigators have stated, as a result of their observations, that under certain conditions pruning increases growth.

As has been discussed in a previous paragraph severe early disbudding in Group B, Experiments I and II resulted in less growth of trunk in girth than the trees in Experiment III. Also a few measurements of trees that were summer pruned to incite growth in resting buds or limbs, or where a leader was severely pinched back indicated less total growth of trees, than trees not summer pruned. Not enough observations were made so that positive conclusions could be drawn.

On the other hand the results of the growth of the trees in Experiment III where the buds had been rubbed off below 24 inches, indicate that a light early disbudding may be of benefit to the trees. Since not enough

trees were under experiment, the results so far are not conclusive on this point.

Experiments covering a period of at least five years are needed to determine the effect on growth of partial early disbudding and pruning as compared with no disbudding and pruning.

Pickering (2) states that, "while it appears to be established from these experiments that the crops are larger and the growth of the tree is greater in proportion as the pruning is reduced, the authors are of the opinion that another series of experiments might demonstrate that a certain amount of pruning may be good and even lead to better results than those obtained from their work, especially with certain varieties of apples which differ largely in their habits and require different treatment. The general conclusions are that pruning should be reduced to the lowest possible limits consistent with the formation of a tree of sufficient sturdiness to bear its crops with safety, which in most cases would mean besides the cutting back after planting a gradual reduced pruning for the first four or five years. Pruning after this time should consist merely in the removal of interfering branches and unripened wood."

A series of experiments have been planned and are included in this thesis to continue the general scheme of heading as has been discussed and also to investigate various problems connected with the amount of pruning and its influence on growth and productions.

Forcing Growth of Inactive Buds.

In both Groups A and B certain trees were noticed that carried inactive buds, short spurs or twigs at places on the trunk, where growing scaffold limbs were desired. Photograph No.29 is an excellent example of such a tree in Group A. At C and D are Prong buds that started growth in the spring from lateral buds, but completed their growth when less than ½ an inch long. At these points primary scaffold limbs are needed. Photograph No.30 is of a tree in Group B. Notice new growth at No. 2.

In order to force inactive buds or twigs into growth a number of trees were experimented on during July and August. On such trees all superfluous growths were either pinched off at the terminal bud or cut back

from 1/3 to 1/2 their length. In no case was it possible to start growth in an inactive bud or twig such as those represented in Photographs Nos. 29 and 30. In nearly every case the vigorous pinched shoot grew again from auxiliary buds near the cut. Pinching was done several times on a number of shoots, without checking growth or starting selected buds into growth. Evidently the pinching back was done too late in the season or was not drastic enough.

With this rule in mind certain experiments are to be tried on trees in this coming summer, in order to find the best method of forcing buds with the least amount of pruning. Such practices must not conflict with the other principles of wide angled limbs and wide spreading habit of growth.

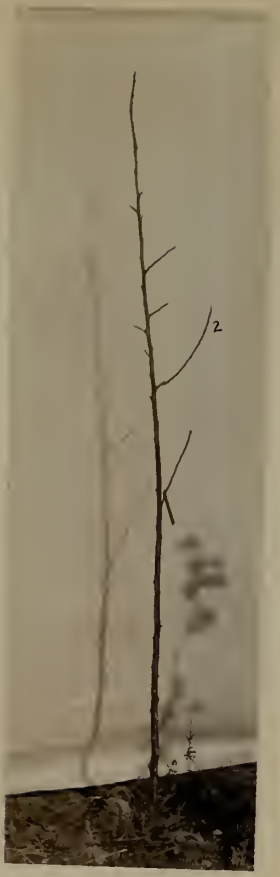
It is not anticipated that a needed limb will fail to grow, when the trunk is disbudded below the desired height of the first limb or when superfluous limbs are pruned off on two year old trees. However, such a condition might occur and to be fore-armed, the following treatments are suggested.

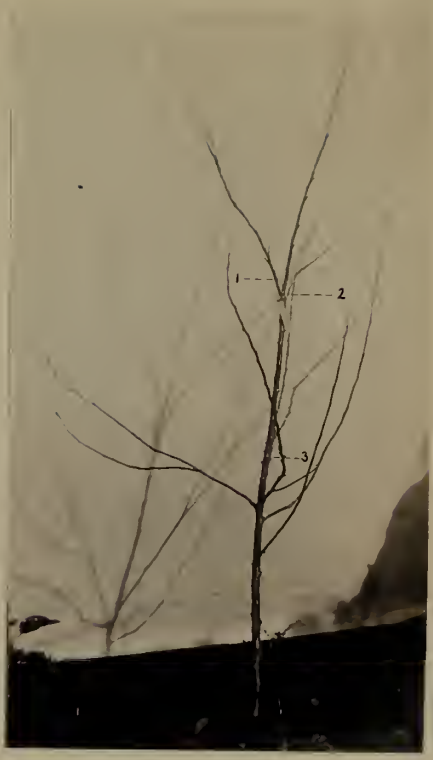
No attempt is made the first year to throw the bud into growth other than making a cut above the bud. Wickson (28) states that, "If for any cause during early summer a bud does not start where wanted, a short transverse cut through the bark just above the bud will cause it to develop into a limb." If this treatment should fail the tree is given a light pruning the following spring before growth starts. Only the superfluous growths are removed or cut back in the vicinity of the backward bud. This proceedure should cause a vigorous growth of the bud.

In the chapter on, "A study of Branch Angles", it was stated that an angle narrower than 60° was undesirable since it was often structurally weak. In addition such an angle generally leads to an upright habit of growth, which we consider a disadvantage in the type of tree for Massachusetts. See tree No. 25 Limb No. 3 and tree No. 23 Limb No. 4. As a general rule a bud starting growth in the spring near the terminal bud of the leader or the pruned end of the leader will make a narrow angled limb with the trunk. This is true especially of two year old trees headed back when a whip at the beginning of the second year's growth. Non headed whips will sometimes develop narrow angled limbs on the leader just below where growth starts the second year.

In Photographs Nos. 31 and 34 the upper two scaffold limbs are narrow angled. Photograph No.29 is of a McIntosh tree having all wide angled branches. These narrow angled limbs are often retained on two year old trees purchased from Nursery men. As the experiments have clearly demonstrated the lower limbs always make wide angles, while the upper limbs are occasionally narrow angled. Fruit growers in planting two year old trees often remove some of these lower limbs, retaining one or more of the upper branches as part of the quota of primary scaffold limbs. Such narrow angled limbs are a constant menace to the tree, when the fruit bearing age is reached. These weak branches are responsible in many cases for broken down scaffold limbs carrying a load of fruit. In closely planted orchards when the lower limbs crowd and are removed, the resulting head is largely made up of such narrow angled limbs. The orchard mentioned on page 3ocontains a number of trees of this order.

Attention will be called in the chapter on the training of young apple trees, to this tendency of the upper buds on the leader to make narrow angled limbs with the trunk.





No. 30 No. 31

Photograph 30 illustrates a tree in Lot B Experiment III.

Photograph 31 is of one of the twelve trees that were planted without any cutting back or thinning of the branches. These trees made a remarkably thrifty growth. See page 56

A METHOD FOR TRAINING APPLE TREES.

In the chapter on Fundamental Principles in Pruning Apple Trees, it was stated that the object of training was the production of more and better fruit, at the least expense to the fruit grower. It was also stated that the basic features of the ideal tree is one having, First, well separated branches, Second, Branches having wide angles, Third, Branches having a wide spreading habit, Fourth, Trees brought to the fruiting period at the earliest possible age.

Due to the widely different habits of growth of our apple varieties, the amount of pruning for each variety after the head is formed will vary. Thus the expense of pruning will be greater for certain varieties than for others. With the systems to be outlined, it is believed that the amount of pruning will be less for all varieties than has to be done under the present methods of Vase heading and annual cutting back.

The fundamental principles of this method, as mentioned in the first paragraph of this chapter have been ascertained by experiments, observations and measurements on apple trees of all ages and many varieties. It is firmly believed that the researches carried out have established the truth of these principles and that they will stand the test of time under practical orchard application.

In fact, the writer has been greatly surprised to find through correspondence with a number of prominent Apple Growers in New York State that they have already successfully demonstrated the practicability of one or more of these principles.

However, further experiments are necessary to make clear certain minor practices. At present it is difficult to give specific and proven advice for the formation of secondary scaffold limbs and the treatment of the leader in the case of all varieties. Until such experimental evidence is at hand, the fruit grower will have to follow the general directions and also use his own judgment. The advice given will cover nearly all cases, but modifications will have to be made in the amount of pruning, and cutting back on the leaders may have to be resorted to with some varieties.

Type and Height of Head During Formative Period.

This method of training trees is adapted to both the Leader and Modified Leader types of head. The writers personal preferance is for the Leader type, the advantages

of which he has attempted to prove in Chapter III on Headsand Heading. In view of the fact that the prejudice against the Leader tree is almost universal and the difficulty of changing established customs, the method for training will also include the Modified Leader type of head.

Height of First Branch.

The height of the first branch above ground will depend on the growth habit of the variety. In deciding on this distance the tree habits of growth as described by Downing (6), namely, wide spreading, upright spreading and upright, will each be assigned a measure within which the first limb of the head will be started. This arbitrary height should be modified when necessary so as to adapt it to peculiarities of growth of any of the varieties. These distances will be somewhat higher than is usually advised for the so called low headed tree. This is due to the fact that the tree is expected to be a wide spreading tree for the variety, when at the age of maximum production. Such a tree will of necessity be a lower headed tree of the variety, than one trained for the Vase type of head and started with the scaffold limbs growing upright. The following heights are recommended for this system of training.

Wide spreading varieties.	First limb.		40' to 60 inches.	
Upright "	"	"	"	30' " 36 "
Upright	"	"	"	18' " 24 "

Number of Branches.

For the Modified Leader tree four or five primary scaffold limbs are enough.

No arbitrary number of branches is recommended for the Leader tree. Each year one or two primary scaffold limbs are added to the head until the tree reaches a height beyond which it is not desired it shall grow. Some varieties as Wealthy, McIntosh, Jonathan, Wagner, and Greening, which make small to medium sized trees, with roundish to spreading flat tops, will not need any restrictions as to height, since the leader naturally breaks up into a few branches. Pruning to keep them within boundswill not have to be resorted to in the majority of cases.

Distance Apart and Arrangment of the Branches.

The distance apart of the primary scaffold limbs will be determained by the character of growth. If the variety tends to grow upright, or form a dense head due to a vigorous twig growth and large leaves, the limbs will be spaced further apart than for those varieties that make the so-called open head. The distance should in no case be closer than 8 inches for the latter type and from 12 to 18 inches for a wide spreading or dense headed type. The proper arrangment of the branches about the trunk is important. The writer believes it advisable to start the first limb to the south, the second to the west, the third to the east and the fourth to the north. That is, the first three limbs are so arranged that they receive the maximum amount of sunlight, which will assure better colored fruit on the lower branches. The following diagrams illustrate the arrangments of branches.

First Year Training.

It is considered that the whip or two year old tree has been well planted, according to the directions given under planting.

As soon as growth starts in the spring the buds on the trunk, if the tree is a whip, are rubbed off below the point decided upon for the first primary scaffold limb. If the tree is a two year old, choose for the first primary scaffold limb one that is already present and is located at the desired height making a wide angle with the trunk. If another limb is present on the two year old tree and extending in the right direction and spaced properly above the first limb, it also may be saved. All the remaining limbs are cut back to stubs except the leader, which must be saved. In selecting two year old trees it is essential to choose only those having a good vigorous straight leader. It is advisable to go over the trees in three or four weeks to note if all the desired limbs are growing. In case a bud remains quiescent, which is quite unlikely provided the trees are vigorous and well planted, the advice given by Wickson (28) is to make a transverse cut just above it to incite growth. Should the first or second limbs of the two year old tree droop to the ground, remove a few leaves just back of the terminal bud. Photograph #23 illustrates the treatment of the whip. It is essential that the buds be rubbed off as early in the spring as possible. Photographs 32 & 33 illustrates the pruning of the two year old whip. The head of this tree was so formed that two primary scaffold limbs could be saved.

Second Year Training.

Keep in mind the type of tree desired. That is the primary scaffold limbs must be wide angled, well separated vertically on the trunk, properly oriented and compelled to grow wide spreading for the first two or three years, to prevent dense heading.

Wide Spreading Varieties.

With varieties having the wide spreading habit of growth, the first three or four primary scaffold limbs should be encouraged to grow spreading or upright in position, at the beginning of the second year, and certainly at the start of the third year. By first encouraging a wide spread to the limbs, an open head is insured and the upper or scaffold limbs will not be interfered with. When the upright direction of growth of the lower limbs is desired, it may be secured by

No. 32

The kind of two year old trees to buy for pruning for separation of branches. The one on the left is listed as XX, and the other as XXX.

No. 33

Two year old trees pruned for planting.

The one on the left has been pruned for the vase form as generally practiced.

The tree on the right has been pruned for the leader type with branches separated. Note that the leader has been left.

cutting back in the spring the superfluous twigs on the leader. Photograph #35 shows a tree at the beginning of its second year. Three primary scaffold limbs have been selected and the remaining limbs cut back to stubs. These stubs should be removed within two years. The leader should not be cut back.

Do not prune or pinch back the terminal bud on any of the leaders of the primary scaffold limbs. The only exception to this rule occuring when a scaffold limb out grows its neighbors. In such a case the leader may be pinched off or cut back during the growing season. The next spring another leader should be chosen to continue the branch.

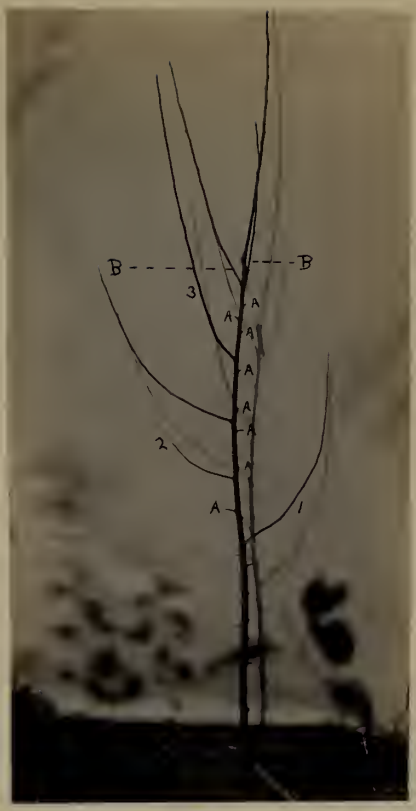
Upright Growing Varieties.

For upright spreading and upright growing varieties the wide spreading habit is secured by not removing any of the limbs on the trunk. The non pruning compels a fight for position among the branches, which produces wide spreading limbs.

The surplus branches may be left on the leader for one or two years, provided they are not allowed to over grow the permanent scaffold limbs. If left on for two years they should be pinched back at the start of their second year's growth. In this way the benefit of their leaf surface is secured for additional growth and spread of branches. When these surplus branches have served their purpose in giving the proper spread to the permanent limbs, they may be pruned off close to the trunk. This pruning should be done just at the start of the growing season. Wounds made in this way will usually heal, on a thrifty young tree, in one year. If very many twigs have to be cut out, it might be advisable to remove a half in the spring, leaving the remainder to be cut away during the summer.

Selection of Primary Scaffold Limbs.

In the case of wide spreading varieties, the selection of the primary scaffold limbs may be desired at the start of the second year, in order to give the upright habit of growth to the selected limbs. A quick way to accurately determine the position of the limbs, is accomplished by having a slender pole six or eight feet long. On this pole the desired distances between the scaffold limbs are marked off. By holding the pole on the first scaffold limb selected and against the leader, the remaining limbs as far as they have been



No. 34

Pruning at the start of the second year.

An unpruned whip at the beginning of the second year. Three branches #1, 2 and 3 should be retained as primary scaffold limbs. The letter A represents prong buds that should not be pruned off. Should, at any point along the leader, a needed branch be missing, one of these buds can be forced into growth. At B and B are narrow angled branches. They should be cut back to stubs or removed entirely.

No. 35

Tree at beginning of second year.

Three branches well spaced and wide angled selected for primary scaffold branches. The remaining branches cut back to stubs to provide additional leaf surface. These should be pruned off in a year or so. The leader should not be cut back except in the case of certain poor lateral forming varieties.

grown can be easily selected. Then cut back the superfluous branches as directed above. In choosing the primary scaffold limbs, care must be taken in selecting the upper limbs on the leader, since these often make narrow angles with the leader. Photograph 34 illustrates the growth of narrow angles at the base of the leader.

With upright growing varieties, or in case a wider spread is desired in the wide spreading variety, no pruning need take place at the start of the second year. In any case the question of whether it may be desirable to do a little cutting back on the surplus branches will be determined by such conditions as the necessity for a wider spread or an upright growth or the development of a primary scaffold limb that failed to grow. Absolute directions cannot be given to fit all conditions.

Remember the control or spread in all cases is determined by competition among the branches for position. Thus the fruit grower must know just the amount of thinning of buds and twigs on the trunk and branches necessary to give the desired direction of growth. This not difficult. In the main, keep in mind the principle of, "Prune as little as possible." Also that dormant pruning will give a growth impetus to the remaining branches and the strength of this growth will be controlled by the amount of pruning. In this way if no pruning has been done the first two or three years and we have a tree full of wide spreading limbs, with one or two limbs needed for scaffold branches that have been over grown by their neighbors, a dormant pruning of the superfluous larger limbs, will suffice to develop these scaffold limbs to their proper size and positions.

Selection of Secondary Scaffold Limbs.

The secondary scaffold limbs are the branches growing from the main or primary scaffold limbs. The first secondary scaffold branch should be located about a foot from the trunk and attached to the primary limb at the side. The second secondary branch should be on theopposite side from the first and about a foot beyond. No limit is placed on the number of secondary scaffold limbs that may be developed on a primary scaffold branch the only restriction being that they must be well spaced. In the development of the Leader tree the lower primary scaffold branches will be larger than the upper primary scaffold branches and will carry a greater

number of secondary scaffold limbs. The trees should be gone over each spring and the limbs thinned out so they will be a foot or more apart. In studying the growth of Leader trees the writer finds that the upper branches are always smaller than the lower branches. For this reason little care need by taken in locating the secondary scaffold limbs on the upper branches since these limbs do not have to carry as great a load as the lower limbs.

Third Year Training.

Modified Leader.

At the start of the third year, for the Modified Leader four or five primary scaffold branches should be present to form the head. If the requisite number of limbs are at hand, the leader should be cut off just above the highest scaffold branch. If not enough limbs are present, continue the leader for another year, for the development of additional branches.

Each primary scaffold limb is trained for its secondary scaffold branches as explained in the paragraph on, "Selection of Secondary Scaffold Limbs."

The secondary scaffold limbs are trained in the same way, with lateral branches grown about the limb at intervals of six inches to a foot. These laterals are not placed on the sides of the secondary scaffold limbs, but may be located at any point about the limb. The distance apart will depend on the twig and leaf habit of growth of the variety. If the variety tends to develop long slender twigs and large leaves, allow the maximum distance apart for such types.

Leader Type.

With the Leader type of tree, the leader is not removed, but treated in each succeeding year in the same manner as outlined for the second year. That is, each year primary scaffold limbs are added to the head, care being taken to space and spread them properly and to have each limb fill its alloted position. Thus limbs numbered 1, 5, 10; 2, 6, 11; 3, 7, 12; 4, 8, 13 should be in the same vertical plane. See photograph #36

Fourth Year to Bearing Age.

Modified Leader Type.

With the Modified Leader tree the head should be completed during the third year.

No. 36

Leader tree at end of third year.

This photograph illustrates the growth of the leader tree at the end of the third year. Five scaffold branches have been selected, well separated and arranged on the trunk. Number 5 is a spur that will develop a satisfactory branch this year. Sub scaffold limbs should be present on numbers 1 and 2.

Leader Type.

For the Leader tree continue the leader and prune as outlined for the second year. Very little pruning is now to be done. In general, cut out any laterals that tend to grow vertically in the tree or that cross or interfere with a well placed lateral. At the start of the fourth or fifth year the special cutting back on the fruiting laterals for such varieties as King is now necessary. This cutting back is done to increase the fruiting area on the branch of varieties, which grow long bare laterals that do not develop sub-laterals readily. King is an excellent example of such a variety. In Photograph No. 37 notice the long bare branches in the top of the tree. These branches carrying short fruit spurs and sometimes a short lateral, rarely two.

The method of cutting back is as follows: The fruiting laterals along the scaffold limbs are pinched back in the spring, leaving about eighteen inches to two feet of the previous year's growth. This leaves twelve to eighteen inches of fruiting wood and room for the development of two or three laterals, which may be pinched back the following year. Laterals that grow near the cut end of a branch may be too close together. In such a case thin out to leave room for the development of future bearing laterals and fruit spurs.

Bearing Age.

The pruning during the bearing age consists in keepting the branches separated on the leader until the tree arrives at the age at which the leader either becomes broken up into a number of small branches and then needs no further attention to spacing, or must be cut back to prevent any further increase in height. The age at which this will occur cannot be given, but will vary for different varieties.

Pruning should consist in thinning out dense places along the branches and cutting out crossing twigs. Most of it should be done on one year old wood for a branch should not be allowed to grow out of position for more than a year.

In time, the spurs may become too numerous or old and produce small and inferior apples. To remedy this condition a general cutting back of the spurs should

No. 37

King, a variety that will need
a little cutting back on the laterals.

be done in the spring before growth starts. This dormant pruning will start into growth certain inactive buds and spurs and cause a vigorous growth of new wood. This new wood will develop a new spur system the second year.

Rules for Pruning Bearing Trees.

(1) Prune as little as possible.

(2) Do not cut back the leaders of the scaffold branches.

(3) Weak growing varieties should be pruned more severely along the scaffold limbs, strong growing varieties, lightly.

(4) Varieties that branch freely require little pruning. Those having unbranched limbs should be pruned more severely.

(5) Rich, deep soils favor growth, prune trees in such soils lightly. In shallow sandy soils trees produce short shoots and the laterals should be cut more closely.

(6) Prune biennial bearers conservatively and yearly.

(7) Prune only to admit light, to produce more vigorous fruit spurs, to produce more bearing laterals and to correct "out of place" growth.

(8) If trees make too vigorous a growth, change methods of culture, rather than to prune severely.

(9) Thin the fruit each year and do not permit enough fruit to hang on the two year old wood of the leaders of the scaffold branches to badly distort them.

(10) Do any severe dormant pruning preceeding a heavy bearing year.

A Study of the Development of Branches on the Leader.

Some difficulty may be experienced after the third year in securing the growth of enough branches on the leader to be able to select primary scaffold limbs in their proper place.

Studies were made on a number of Wealthy, Duchess, Wagner, and other varieties to determine the position, angle of limbs and number of limbs as found on unpruned leaders from two to five years old. The following facts were ascertained.

First. The unpruned leader develops but one or two branches on the two year old wood and a number of spurs. The branchee are usually near the end of the year's growth.

Second. As each year's growth of the leader increases in age more limbs tend to develop.

Third. Limbs at the end of the year's growth may be narrow angled. Limbs four inches or so back from the end of the growth are always wide angled.

The following table will illustrate these facts. These Wealthy, Duchess and Wagner trees had been trained to the Vase form when planted and five to eight scaffold limbs allowed to grow. These limbs had not been pruned for four years and each in its self was analogous to the leader in a leader tree, except that probably there was not the development of primary scaffold limbs that would have occured if it had grown alone. But for our purpose it served to demonstrate the growth of an unpruned leader. See Photograph Nos 38139

TABLE VIII.

Number of laterals on each year's growth on twenty two leaders as counted and measured on seven Wealthy trees.

Length of Laterals

Year	6"	12"	24"	36"	48"	60"	72"	80"	Tot No.	Av. No.
1914	5	8	5						18	.8
1913	28	26	14	9	8	1			88	4.0
1912	4	6	8	20	15	12	9		74	3.3

26 Leaders on 8 Duchess Trees.

Length of Laterals

Year	6"	12"	24"	36"	48"	60"	72"	80"	Tot No.	Av. No.
1914	14	26	8						48	0.5
1913	10	30	20	16	2				78	3.2
1912	4	9	13	9	16	18	18		87	3.4

No. 38

A Wagner tree used to study the branch development on the leader. Note the upright growth of these leaders and the branches and spurs on the older wood.

No. 39

A Duchess tree studied for the development of branches in the leader.

36 Leaders on 10 Wagner Trees.

Length of Laterals

Year	6"	12"	24"	36"	48"	60"	72"	80"	Tot No.	Av. No.
1914	11	13	8	1					33	.9
1913	39	24	21	19	3	1	1		108	3.0
1912	6	19	14	8	9	12	7	5	80	2.2

This table reveals the fact that on the two year old wood on these leaders, there was nearly an average of one branch. On the three year old wood there was an average of three branches for Duchess and Wagner and four branches for Wealthy. The number of laterals developed since 1912 on the 1912 wood averages from a little over two to nearly four, but in two cases the growth of the 1912 wood averaged only 1½ feet. These measurements demonstrate that when the leader tree is three or four years old or older that there may not be well placed and wide angled primary scaffold limbs present on the two year old wood of the leader. In such a case the table shows that by waiting until the wood is three or four years old the necessary limbs will probably be present. In case there are only narrow angled, poorly located branches on the two year old wood, these laterals should be severely cut back or entirely removed with also a slight thinning of the spurs below. This pruning should stimulate the growth of the remaining spurs so that the next spring the desired branches will be present. Free growing varieties as Baldwin, Spy, McIntosh, Wealthy, Ben Davis, Rhode Island Greening, and Red Astrachan will rarely have to be treated in this manner. The greatest difficulty will be experienced with King and like varieties that do not develop branches or twigs readily. With these varieties it may be necessary to head back the leader six inches or so each year. This will cause the development of a number of laterals, of which a choice may be made for primary scaffold limbs and an upright growing lateral to continue the leader.

PROJECT FOR AN EXPERIMENT IN PRUNING APPLE TREES.

In order to test the ideas embodied in this thesis, the following experiments are planned to compare methods of heading and pruning apple trees to ascertain their effect on the tree, their costs and practical value in the orchard. These types of heads are as follows:

1. The globular or vase head
2. The modified leader head
3. A new form of the true leader head
4. An unpruned head

There will be included also

5. A comparison of the effect of heading in and not heading in on types (1) and (3).

These methods of heading and pruning will be tested on five varieties of differing habits as to

1. Effect on heighth, spread, density, and general habit and vigor of growth;
2. Fruit production comparing age of fruiting, position of fruit on the limb, regularity of bearing, quantity and quality of fruit produced;
3. Labor costs including pruning, spraying, thinning and picking.

Location and Plan of Orchard.

This experiment is to be located on the Tuxbury land between Pleasant street and the brook. It should yield results from the first year and it is hoped that it may remain as a permanent orchard. If we are compelled to vacate the land, valuable results should still be secured. There may be 10 rows the entire length 710 feet. Permanent trees to be between 40 and 45 feet apart, the semipermanents bringing it down nearly to 20 feet and fillers to about 10 feet.

The fillers may not come into bearing but will yield valuable results on the methods of forming heads and may then be removed or the scaffold limbs broken down under test to ascertain their strength.

There will be two rows each of five varieties. Of the types planned as permanents there will be 20 trees of each treatment in each variety, arranged on two groups of eight trees and one group of four trees. In the eight tree groups two trees remain as permanents and in the four tree group, one tree. The types planned as semi-permanents are to be interspersed among the other types and disposed in exactly the same manner but they will come out at the age of, perhaps 20 years.

This arrangement is more clearly shown on the attached partial plan.

Varieties

The varieties to be used are as follows:

(1) Baldwin principally on account of its commercial importance.

(2) McIntosh, for the same reason.

(3) Northern Spy, a vigorous, upright, dense headed variety.

(4) Rhode Island Greening, a vigorous, spreading, moderately dense headed variety, bearing green apples.

(5) Tompkins King, a strong growing open headed variety.

Methods to be Followed in Developing the Heads.

(1) The true Leader type; not pruned.

The leader to be allowed to develop without cutting back until the tree is 16 or 20 feet high. The main scaffold limbs to be spaced 8 to 12 inches apart and placed #1 pointing to the south, #2 to the east, #3 to the west, and #4 to the south, branch #1 to be 24 to 42 inches from the ground. Higher scaffold limbs

to be arranged in a similiar manner. Secondary scaffold limbs to be spaced on the primary scaffold limbs and not allowed to outgrow the leader of the primary scaffold limb. Later pruning to consist in removing superfluous and interfering branches. No heading back unless where a side branch outgrows its leader or where a scaffold leader outgrows its neighbors. Attention to be given to securing a wide angle of the main scaffold limb.

To be planted as permanent trees.

(2) The leader type, headed in.

To be treated as (1) except that primary and secondary scaffold branches to be headed in each year 1/5 to 1/3 their growth. Interfering and superfluous branches to be removed as in (1).

To be planted as semi-permanents.

(3) The modified leader type.

To be pruned exactly like (1) except that the leader is cut out after the first four scaffold branches are started.

To be planted as permanent trees.

(4) The "unpruned" tree.

To be grown with as little pruning as possible, leader allowed to grow as is (1). No attention to be given to placing scaffold limbs or securing wide angles. Interfering and superfluous branches to be removed where absolutely necessary.

To be planted as semi-permanents.

(5) The globular type, not headed in.

Leader to be cut at 24 to 42 inches according to the variety. Three to five scaffold branches to be developed as well spaced as possible under the circumstances, to form a well balanced head. Interfering and superfluous branches to be removed and weak crotches prevented. No heading in unless necessary to prevent a branch outgrowing its neighbors.

To be planted as permanent trees.

(6) The globular type, headed in.

To be pruned exactly like (5) except that all strong shoots are to be cut back 1/3 to 1/2 their growth annually.

Note:- All trees to be one year whips 4 to 5½ feet according to variety when set.

Methods of Securing Data

On growth and habit

(1) Trees to be calipered each fall at a small nail on the trunk about 1 foot from the ground and on each of the main scaffold limbs about 4 inches from the trunk.

(2) All prunings to be weighed immediately after removal.

(3) Height and spread of trees to be measured annually.

(4) Leaf weights to be taken annually by selecting the 6th leaf from the end of a string shoot, or if damaged, its nearest sound neighbor. When the trees are under five years old 10 leaves will be enough; after that a larger number to be taken as the trees increase in size. The leaves to be kept until thoroughly air dried and then weighed.

(5) At least one tree of each treatment to be photographed periodically, perhaps every three years, preferably in winter.

(6) General notes on the appearance of the trees to be made annually.

On fruiting habits.

(1) The yield to be taken annually in pounds and either the number of fruits or their average size: also the proportion of Fancy, A grade, B grade and culls.

(2) The position of the fruits whether terminal, lateral or on spurs.

(3) The color and quality of the fruit.

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